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CONSERVATION RESERVE PROGRAM

ENVIRONMENTAL RISK ASSESSMENT

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.CONSERVATION RESERVE PROGRAM: ENVIRONMENTAL RISK ASSESSMENT

I. INTRODUCTION

BACKGROUND

The Conservation Reserve Program (CRP) is authorized under Subtitle D of Title XII of the Food Security Act of 1985, as amended. The statutorily mandated purpose of CRP is to assist owners and operators in conserving and improving soil, water, air, and wildlife resources on their farms and ranches by converting highly erodible and other environmentally sensitive cropland to permanent resource conserving covers for 10 to 15 years. The CRP is the Department of Agriculture's (USDA's) largest single conservation program. As many as 36.4 million acres of environmentally sensitive cropland have been enrolled in the program. Annual costs have reached nearly $2 billion and the program has produced substantial soil erosion reduction, water quality improvement, and wildlife habitat enhancement benefits.

Authority to continue enrollment in CRP is included in Title III of the Federal Agriculture Improvement and Reform Act of 1996 (1996 Act). Under the 1996 Act, enrollment can be maintained at up to 36.4 million acres through 2002. Discussion prior to passage of the act suggests that the CRP should be administered to address the most severe ecological problems resulting from cropland cultivation and management activities in the most cost-effective manner. Because the actions taken under the CRP rulemaking process will affect the economy by more than $100 million per year and will have a significant effect on the environment, the Federal Crop Insurance Reform and Department of Agriculture Reorganization Act of 1994 requires that an environmental risk assessment be conducted.

The traditional risk assessment consists of a description and technical evaluation of the information characterizing the relationship between environmental stressors and elements of the resource base (i.e., ecosystems) and the resulting adverse impacts. Uncertainties associated with the possible cause and effect relationships and the extent of the effects are also stated. For CRP, these relationships involve the linkages between agricultural activities on the land (primarily cultivation and management for crop production) and the stresses or negative impacts these activities place on land, water, air, and wildlife resources.

In many instances, relatively modest changes in management practices or the addition of certain structural practices on the land that allow continuation of the basic set of agricultural activities are adequate to alleviate most of the adverse impacts. However, in some instances, major changes in land use must occur, such as conversion to a non-cropping use, to mitigate the problems. The CRP is designed to address these situations and conditions. This feature differentiates CRP from other USDA land management and use modification programs such as the Environmental Quality Incentives Program, highly erodible land conservation compliance, wetland conservation compliance, and much of the conservation technical assistance provided by the Natural Resources Conservation Service.

Many risk assessments involve a description and assessment of a single, clearly identified stressor with information to develop fairly clear indications of the type and extent of the

adverse impacts on human welfare and the environment. Examples of such situations could include potential importation of a new agricultural pest or disease, discontinuation or introduction of a new pesticide, or modifications to food safety monitoring and control systems.

However, assessment of the risks to the environment associated with agricultural production activities is much more complex. Activities undertaken for crop production form a very interdependent and complex system of cause and effect linkages with the natural resource base, including feedback mechanisms and buffers. Often, there are long and varying time lags associated with the occurrence of an event or activity and its impact on one or more elements of the resource base. Also, because of the large and diffuse set of cropping activities and farming operations, it is difficult to trace the impacts back to the original source. Further, similar environmental impacts can be caused by non-agricultural activities, e.g., point source pollutants, and isolating the specific cause and impact relationships is often very difficult. Finally, other factors that are clearly outside the control of farm producers, such as weather and market forces, further complicate the diverse, complex and dynamic set of environmental cause and effect relationships associated with agriculture cropland use.

Because of this incredible complexity and diversity, it has been extremely difficult to establish detailed and consistent databases to empirically describe the stressor-environmental component relationships and their impacts. These information shortfalls illustrate the uncertainties associated with supporting the hypotheses established in the assessment. These data limitations and the associated uncertainties will be highlighted in the discussion and analysis presented in the assessment.

ECOLOGICAL RISK ASSESSMENTS

This ecological risk assessment for CRP is based on processes described in the Environmental Protection Agency (EPA) publication, Framework for Ecological Risk Assessment (U.S. EPA 1992). According to EPA, an ecological risk assessment is the process that evaluates the likelihood (and amount) of adverse ecological effects that may occur or are occurring as a result of exposure to one or more stressors. A "stressor" is defined as any physical, chemical, or biological activity or agent that can induce an adverse impact. The primary purpose of the CRP risk assessment is to identify and describe the major ecological concerns related to the cultivation and management of agricultural land for crop production, to quantify and evaluate the adverse environmental impacts and risks resulting from cropping activities on the soil, water, air, and wildlife resources base (i.e., the endpoints), and to estimate the consequences if no mitigating actions are undertaken.

The risk assessment involves three major steps: (1) problem formulation, (2) ecological effects analysis, and (3) risk characterization. Problem formulation includes a basic verbal or graphic characterization of the conceptual model of the adverse environmental cause and effect relationships associated with production activities on agricultural cropland. The conceptual model depicts the working hypotheses of how the stressors may affect ecological

components and the relationships between assessment and measurement endpoints, the data required to describe these relationships, and the methodologies used to analyze the data and describe the exposure scenarios.

The analysis phase of the assessment tests the hypotheses depicted in the conceptual model. Potential adverse cause and effect relationships between stressors and ecological components are evaluated, including an empirical description of the extent and distribution (spatial and temporal) of the contact between the stressors (e.g., eroded soil) and the ecological elements of concern (e.g., water). When an entity or relationship depicted in the conceptual model cannot be quantified, qualitative narrative is provided, including a statement of the associated uncertainties. This information is used to develop summary profiles of exposure and ecological effects that serve as input for risk characterization.

The third phase of the assessment, risk characterization, evaluates the significance, or likelihood, of adverse ecological effects resulting from exposure to a stressor. The evaluation includes the types, magnitudes, geographical and temporal distribution of the effects and associated risks, and the likelihood of recovery.

The information included in the three stages of the risk assessment can be used to assist CRP program managers in developing program policies to enroll acreage that will provide the highest level of environmental benefits for the program funds expended.

II. PROBLEM FORMULATION[1]

This risk assessment identifies the ecological risks to the environment of agricultural operations and production practices on cropland (the agricultural land use CRP targets). Specifically, the assessment identifies the crop production activities and resultant factors that threaten, or stress, the resources at risk in the cropland ecosystem, the ecological elements or components that are stressed, and the potential adverse ecological consequences of the identified stressors.

This section includes the following information: (1) identification and description of the assessment endpoints (the environmental or ecological values to be protected), (2) identification of the production activities that, in combination with natural factors, create conditions of stress to the environment, and (3) description of the most likely risk scenarios or probable adverse impacts and outcomes resulting from the cropping activities.

ASSESSMENT ENDPOINTS (RESOURCE VALUES AT RISK)

Human activities occurring in the process of producing agricultural crops, when combined with the natural factors (soils, weather, and topography), can create situations and entities that stress elements of the natural environment. Some of these activities include cropping practices (e.g., cultivation and harvesting), irrigation, fertilization (chemical or animal waste), pesticide application, and alterations of lands (e.g., clearing forests, draining wetlands, etc.). These activities can cause adverse environmental effects, such as accelerated soil erosion and compaction, reduced soil tilth, contaminated surface and groundwater, reduced air quality, and losses of wildlife habitat.

Recognition of these relationships, plus a review of the CRP legislative provisions included in the Food Security Act of 1985, the Food, Agriculture, Conservation and Trade Act of 1990, and the Federal Agriculture Improvement and Reform Act of 1996, provide guidance in establishing the major environmental endpoints for this assessment. The endpoints include the following:

(1) Soil Productivity (or Quality)
(2) Water Quality
(3) Wildlife Habitat
(4) Wetland Functions and Values
(5) Air Quality

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[1]Much of the material presented in this section was taken directly from a risk assessment for the Environmental Quality Incentives Program, prepared by the Natural Resources Conservation Service.

Soil Productivity (or Quality)

Soil productivity or quality is determined by a set of many highly correlated physical, chemical, and biological properties, such as soil depth, water-holding capacity, bulk density, nutrient availability, organic matter, microbial biomass, carbon and nitrogen content, solid structure, water infiltration, and crop yield. The change in soil productivity is a function of several factors, including climate, hydrogeology, and cropping and cultural practices. Soil quality degradation occurs through physical, chemical and/or biological processes.

Soil erosion and resulting sedimentation is the major cause of non-point source pollution that threatens water resources. The impacts of excessive soil erosion and resulting sedimentation include the following: reduced soil productivity; impaired aquatic habitat; destruction of sport and commercial fisheries and shell fisheries; lost reservoir capacity for flood control, power generation, and potable water supplies; excessive flooding; impaired navigation; aggradation of irrigation and drainage channels; lost productivity of lands swamped by deposition and infertile overwash; increased levels of water treatment required; lost or declined recreational opportunities; and impaired aesthetic values.

The amount of sediment in a stream can affect channel shape, sinuosity, and the relative balance between riffles and pools. Excessive sediment in a stream causes a decrease in channel capacity, which, in turn, results in more frequent and larger floods. In addition to the adverse physical effects of sediment loads (smothering spawning grounds and bottom dwelling benthic organisms and preventing fish and other organisims from finding food), many nutrients, pesticides, and heavy metals are adsorbed onto fine sediment particles, which may result in eutrophic or toxic waters. Indirect effects of increased sediment loads may include increased stream temperatures and decreased intergravel dissolved oxygen levels.

Erosion and compaction are two major physical processes which can degrade soil productivity. Erosion is a function of both human induced and natural factors. Human induced factors consist primarily of the farmer's use and management of the land. Natural factors that effect erosion rates are physical parameters, including geology, hydrology, rainfall, soil texture, and topography. Sheet and rill erosion, gully erosion, and scour erosion are natural processes, but have been greatly accelerated in many circumstances as a result of cropping and other land disturbance or alteration activities.

Erosion in many regions of the country has reduced on-farm soil productivity and contributed to offsite water-quality problems. Soil compaction from heavy machinery and mismanaged livestock grazing also degrades soil quality. On-site soil compaction impedes seedling emergence and decreases water infiltration. This creates off-site problems resulting from higher surface runoff of rainwater and increasing water-related erosion.

Salinity and acidification are forms of chemical soil degradation that lead to significant crop yield reductions. Biological degradation of the soil (or loss of organic matter) significantly adversely affects the physical and chemical properties of the soil. Biological degradation may

be a consequence of production agriculture, if proper cultural, management, or conservation practices are not utilized.

A soil's infiltration rate and its ability to adsorb pollutants depends in part on its physical, chemical, and biological characteristics. Also, the prior soil moisture content markedly affects the amount of water that can infiltrate. The infiltration rate affects the ratio of surface flow to subsurface flow. With an increase in the infiltration rate, the pollutant load associated with surface water runoff should decrease.

The amount of organic matter and clay particles determines the adsorptive capacity of a soil. Sandy soils generally have high infiltration rates and low water holding capacity because of large soil particles and relatively large pores through which water can percolate. Because the total particle surface area and the total negative charge of sandy soils are lower, their adsorption capacity is generally much less than that of clay soils. Soils that are both well drained and contain a sufficient amount of clay and organic matter will absorb the most pollutants and plant nutrients

Subsoil characteristics may either retard or enhance internal drainage and influence the proportion of surface and subsurface flow. Natural barriers, such as claypans or fragipans, reduce the downward movement of water through the soil.

Soil compaction results in decreased infiltration, increased runoff and reduced water holding capacity. Soils that are disturbed during this process are at greater risk of erosion through wind and runoff as the plant cover can be greatly reduced. This can reduce air quality and water quality due to soil transport in air or water.

With limited moisture, plants exhibit an initial response through reduced production, carbon dioxide conversion, production of food and forage for wildlife and livestock, and total plant cover. This may lead to increased soil erosion and deposition, and decreased water quality.

Surface Water and Groundwater Quality

Potential surface and groundwater quality problems arise from both natural and anthropogenic activities. However, the cumulative impact of human activities including agriculture, development of previously undisturbed forest, range, and wetlands, recreation, transportation, resource extraction, and industrial activities have accelerated the deterioration of the nation's water resources. There have been a significant number of federal, state and local government, as well as, private initiatives developed to enhance water quality. Although there are numerous success stories for water quality improvement and restoration of ecosystem integrity, the national goal of "fishable and swimmable" waters has not been attained in some areas.

Data on water quality is incomplete regarding the spectrum of contaminants released into the environment and their cumulative impacts. Only a small fraction of the Nation's water impoundments and stream and river miles have had consistent monitoring programs developed for data collection and analysis. This data set is even less substantial for the assessment of the quality and quantity of the Nation's groundwater. Because of the lack of data, there are conflicting assessments of how successful water quality programs have been.

There are many sources of pollution from crop production activities affecting the Nation's surface and groundwater supplies. Siltation, nutrients, organic matter, and salts are some of the contaminants affecting surface water. Groundwater supplies are impacted by agricultural sources, such as animal wastes, fertilizers, and pesticides. The destruction of wetlands that protect the quality of surface and groundwaters, has been slowed, but wetland losses still occur.

Evidence from the limited monitoring and assessments conducted on groundwater supplies suggests that the shallowest aquifers are at greatest risk from contamination from human activities. Presently, deep aquifers are believed to be relatively free from contamination. However, an EPA survey shows that about 20 percent of all drinking water aquifers are contaminated to some degree by man-made chemicals.

On-farm applications of fertilizers directly contribute to the degradation of surface and groundwater quality because of adverse cumulative effects and, in some cases, excessive application. For example, 60 percent of the soil samples tested in 12 States had high or more-than-needed levels of phosphorous (USDA 1996b). Sixteen additional States had excessive soil phosphorous levels in 40-59 percent of their soil samples. Ten other States reported that 30-39 percent of the soil samples processed had levels of soil phosphorous above crop uptake needs.

Sensitive geologic formations occurring on cropland affect the transport and delivery of pollutants to groundwater. One of the most frequently occurring landforms that has a major impact on this is karst topography. Fifteen percent of the land mass of the continental United States, excluding Alaska, is classified as karst. Important avenues for groundwater pollution in karst areas are sinkholes, which are openings that develop where shallow surface deposits are over limestone bedrock. Sinkholes form when water moves through soil into fractures in the bedrock and dissolves the limestone, leaving voids below the surface. Over time, the voids enlarge and collapse occurs. Unfiltered water then can enter the collapsed areas and groundwater system. The result is that activities on land can harm groundwater quality in aquifers that serve as sources of water for rural and municipal wells.

Activities that can harm groundwater through sinkholes vary. Sinkholes have been used for disposal of hazardous materials, such as chemical residues in pesticide containers and other chemicals used on the farm. In some cases, they have even been used for disposal of dead animals. Sinkholes provide a direct pathway for pollutants, such as feedlot runoff, to reach the groundwater.

In a survey of farmers' perceptions and attitudes toward sinkholes, Huber (1990) found the following:

> "Owner/operators of land with sinkholes acknowledged several possible sources of groundwater pollution through sinkholes, including some not generally recognized by the public, such as feedlot runoff into sinkholes. Most thought sinkholes were a threat to safe drinking water, and most felt runoff from agricultural land into sinkholes was why they were a threat. Many farmers were taking steps to address runoff into sinkholes; they were most receptive to additional options that would not disrupt their farm operations. Most were concerned about runoff into sinkholes, and it appeared that significant changes to address pollution through sinkholes will not be made without government involvement. They felt appropriate cost-share assistance for practices to control runoff into sinkholes needed to be slightly higher than levels normally provided to encourage adoption of these practices.

Wetlands

From 1954 to 1974, an average of 398,000 acres of wetlands were lost due to land use conversions, 87 percent due to drainage for agricultural production. From 1974 to 1983 an average loss of 157,000 acres of wetlands occurred, 50 percent due to agriculture. And from 1987 to 1991 an estimated 27,000 acres of wetlands per year were lost, 27 percent due to agriculture, (1954-1974 data from Frayer et al. 1983; 1974-1983 data from Dahl and Johnson, U.S. Department of the Interior, 1991; 1982-1992 data from the USDA 1992, which excludes Federal lands).

Although drainage of wetlands, hydric soils, and other sensitive areas has been necessary to develop highly productive cropland, improve navigation on inland waterways, and protect human health and safety, it has also placed stress on the environment by reducing critical water regimes which support plant, animal and micro-organism species' habitats. Areas of wetlands that have been drained since Colonial times has been substantial, with over 53 percent of original wetland acreage affected. Draining wetlands reduces the capacity of the environment to "clean" water through filtration of waterborne sediments, chemicals, and nutrients and the beneficial actions of bacteria as water passes through wetland areas. Wetland-supported vegetation absorbs and assimilates many of the wastes or toxics from agricultural production, filtering the water for reuse. The disappearance of these wetland filtration systems effectively causes more pollutants to enter both surface- and groundwater supplies. The overall results include poorer water quality for aquatic plants and animals and other water-dependent wildlife and increased costs for water filtration and purification.

Wildlife Habitat

Endemic and migratory animal species are impacted from anthropogenic activities and stressors. Stressors that have had a major impact on wildlife habitat, wildlife species and population dynamics, include accelerated sedimentation to streams, excessive application of fertilizers and chemicals, alteration or conversion of wetlands, desertification, and conversion of woodland, prairie, and riparian zones to cropland.

Modernization of American agriculture has increased specialization in commodity production. reducing traditional mixed crop and livestock production. Consequently, millions of acres needed to produce grain and forage for draft animals (e.g., planted acreage of oats declined from 48 million acres in 1954 to about 8 million acres in 1994 and hay acreage declined from 78 million acres in 1944 to 60 million acres in 1992) became available to grow crops for animal feed and human consumption (Knutson et al. 1992, Doering 1992). Recent decades have witnessed larger, more successful agricultural producers absorbing the assets of smaller, less effective operators (Dalberg 1992). In response to the need to increase production efficiency, crop fields have become larger, crop diversity has decreased, crop rotations have become less diverse and more infrequent, and agrichemicals (e.g., pesticides and fertilizers) have become essential to maintaining high-yields.

The negative effects of intensive production of crops on wildlife habitat were magnified in the 1970's in response to increased global demands for American agricultural products. Reacting to higher demand and prices, American farmers were motivated, as well as encouraged, to expand production by planting "fence row to fence row", cultivating existing croplands more intensively, and bringing new less-fertile lands into production (Cochrane 1993, Opie 1994). The repercussions of this intensified land use were further forfeiture of natural cover, small woodlands and shelterbelts, reduced crop diversity, and a concurrent decline in wildlife populations associated with agricultural land use (Taylor et al. 1978, Edwards et al. 1979, Warner et al. 1984, Baltensperger 1987). Efforts to obtain maximum production has diminished the amount and quality of essential components of year-round habitat (e.g., idle grass-dominated escape or winter survival cover) or totally eradicated areas necessary for long-term survival of wildlife populations (Opdam 1990). These factors directly affected the ability of agricultural ecosystems to support populations of wildlife traditionally associated with past, more ecologically diverse agricultural lands.

Changes in habitat distribution and quality associated with agriculture have had other, less obvious effects on wildlife populations. Avian species' richness and abundance in agricultural ecosystems are influenced by the amount of habitat edge relative to field area (Best et al. 1990). As a consequence of elevated efforts to maximize production efficiency, the amount and availability of high-quality cover for many species of wildlife has decreased in regions of intense agricultural production, such as in midwestern Cornbelt States (Warner 1992, Rodenhouse et al. 1993). Reduced availability of nesting cover, higher predator-prey ratios in agricultural landscapes, lower diversity within and between remaining vegetation associations, and the tendency for predators to concentrate foraging in vegetation edges have contributed to

lower reproductive success for birds nesting in agricultural landscapes (Potts 1980, Rodenhouse and Best 1983, Cowardin et al. 1985, Petersen et al. 1988).

A greater dependance on monocultures, with minimal rotations between crops, has resulted in a greater dependance on chemical fertilizers and pesticides to maintain high yields. Current use of synthetic pesticides in the United States is 33 times greater than in 1945 (Pimentel et al. 1991). Of the estimated annual average of 273,476 tons of pesticides used from 1990 to 1992, 68 percent are herbicides, 10 percent insecticides, and 7 percent fungicides (USDA 1994). Greater use of agrichemicals has been implicated in the long-term decline of species such as the northern bobwhite quail (Brennan 1991), decreased fertility in avian species (Shugart 1980), lower reproductive success in fish (Leatherland 1992) and bioaccumulation in aquatic vertebrates with potential adverse affects on wildlife preying on those species (Hall and Kolbe 1980). Direct mortality from insecticides on wildlife can be massive. For example, carbofuran has been attributed to be responsible for the annual deaths of one to two million birds (EPA 1986 cited by Curtis et al. 1993).

Although considerable mortality and reduction in population viability for some species is attributed to pesticides, the indirect effects of these chemicals may be even more damaging (Palmer and Bromley 1992, Curtis et al. 1993). In addition to direct physiological affects on wildlife health, pesticides have the potential to influence reproductive success through elimination of the invertebrate prey base necessary for chick survival and growth (Grue et al. 1989, Chiverton and Sotherton 1991). Agrichemical applications frequently coincide with the breeding season and when young birds are highly dependent upon invertebrates. Many of the insecticides applied to crops are either acutely toxic to waterfowl and the young of ground nesting birds or the insects and other invertebrates needed by both adult and juvenile birds.

Agricultural production and governmental farm program policies have had substantial effects on habitats and populations associated with grassland ecosystems. The lands once defined as tallgrass prairie, much of which is within the intensively farmed Cornbelt region, are 98 percent tilled (Sampson and Knopf 1994). Approximately 30 percent of the shortgrass prairie has been converted to the production of agricultural commodities. The effects of agricultural production have contributed to at least 55 grassland wildlife species being listed as threatened or endangered in the United States.

Midwestern declines in eastern meadowlark populations have been attributed to increased dependance on monoculture-based agriculture and removal of livestock from much of the agricultural landscape resulting in a decline of land devoted to pasture and hay production (Warner 1994). Populations of grassland bird species such as the Savannah sparrow, bobolink, dickcissel, and grasshopper sparrow were reported to have declined by more than 95 percent in Illinois between 1957 and 1983 (Graber and Graber 1983). Breeding bird surveys indicate that continental populations of many native birds of the North American prairies changed rapidly between 1966 and 1991. Grassland birds, especially those endemic to grassland ecosystems have experienced more consistent and geographically widespread

declines in numbers and distribution than any other guild of North American species (Knopf 1994, 1996).

Wildlife species endemic to grassland ecosystems are susceptible to habitat fragmentation and isolation within landscapes dominated by changes in land use. The expansion of riparian forests along major western rivers due to changes in hydrologic regimes below impoundments and planting of shelterbelts/windbreaks associated with agriculture have generally been to the detriment of avian species endemic to grassland ecosystems (Knopf 1992, 1994). Introduction, or invasion, of woody plant species within grassland ecosystems provides habitat for wildlife species more characteristic of eastern deciduous forests (Knopf 1992, Benedict et al. 1996). Increases in the number of alien and exotic species resulting from structural and physical changes in grassland ecosystems have contributed to population declines, or extermination of narrowly-endemic species. Conversion to crop production, habitat fragmentation, and changes in cover type composition within grassland communities have been shown to influence the composition of predator communities (Fleskes and Klass 1991) and rates of nest parasitism (Johnson and Temple 1990, Robinson et al. 1993) resulting in lower reproductive success for species of grassland-dependent birds. Many of the more inconspicuous species of mammals associated with grasslands, such as the white-tailed jackrabbit, badger and spotted skunk have decreased in distribution due to agriculturally-related isolation of remaining grasslands (Lovell et al. 1985). Extensive changes in habitat composition and distribution resulting from agricultural production probably have had significant, negative impacts on populations of many species of small mammals, many of which are primary prey species for larger predatory species

Other land use activities and policies during the past 150 years have led to drastic declines in the environmental health and productivity of many aquatic ecosystems associated with agricultural land use. Stream channelization and conversion of floodplain habitats to agricultural use have been extensive with ensuing harmful impacts to riverine habitats. The extensiveness of stream channelization is illustrated by more than 22,000 miles of channelization in Minnesota (Funk and Ruhr 1971) and in excess of 3,000 miles in Iowa (Bulkey et al. 1976). Channelization of riverine ecosystems eliminates aquatic habitat resulting in channelized reaches supporting a lower biomass of fish species (Paragamian 1990) and a diminished capability for terrestrial wildlife species dependent on the physical characteristics of non-channelized riverine habitats and the aquatic resources they support (Allen 1988).

Agriculture accounts for over 50 percent of suspended sediments discharged into surface waters (USDA 1987). This percentage is even higher in geographic regions dominated by agriculture. In 1982 the total amount of soil eroding from cropland was estimated to be nearly 3.1 billion tons/year (Zinn 1993). The amount of eroded soil entering waterways each year has been estimated to range between 675 million and 1 billion tons (NRC 1989). In 1984 excessive amounts of siltation were estimated to affect 46 percent of all streams and was identified as the most important factor limiting the availability of useable habitat for fish (Judy et al. 1984). The effects of excessive amounts of soil entering surface waters include increased turbidity, loss of micro and macro diversity within wetland substrates, extreme

fluctuations in water temperature, and outright loss of habitat area. Nutrients (primarily phosphorus and nitrogen) introduced into surface waters through solution or suspended sediments stimulate eutrophication which ultimately can significantly deplete dissolved oxygen levels. The changes in physical structure of aquatic substrates and chemical characteristics of the water column induced by sedimentation ultimately diminish the ability of surface waters to support desirable populations of aquatic wildlife. The detrimental effects of sedimentation extending from agricultural inputs are broad enough that they negatively influence estuarine ecosystems and their associated fish and wildlife resources (Simenstad 1983, Odum et al. 1984).

The amount of wetlands present in the conterminous United States prior to European settlement are estimated at 215 million acres (Department of the Interior 1988). By the mid 1970's only 99 million acres remained. Agricultural land use has had the most significant impact on wetland losses. During the period between the mid 1950's and 1970's, agricultural development accounted for 87 percent of wetland conversions to other land use as compared with 8 percent lost to urban development and 5 percent loss to all other types of development. About 50 percent of the wetlands drained after the mid 1970's were used for agricultural purposes (Dahl and Johnson 1991). Wetland losses represent impacts to both resident and migratory wildlife. In addition to outright loss, agricultural use has depleted water tables, allowed excessive erosion to turn small clear-flowing perennial streams into intermittent surface waters, permitted seasonal dewatering of streams, and eliminated small headwater springs and marshes (Rabeni 1996), further impacting habitat quality and the distribution of wildlife resources.

Habitat quality for migratory waterfowl, as well as numerous species of non-migratory wildlife, has been severely affected by agriculturally-related wetland losses in the Prairie Pothole region, central Great Plains, and the Lower Mississippi Alluvial Plain. Federal government subsidies to convert prairie potholes to cropland continued through the 1970's (Department of the Interior 1988) permitting most of the easiest and least costly wetlands to be converted to agricultural production. These ephemeral and temporary wetlands are, however, critical in the reproductive ecology of waterfowl by permitting dispersal of breeding pairs and provide the invertebrate prey base essential for breeding waterfowl and their offspring. The highest concentrations of breeding waterfowl occur on the more temporary wetland types (Kantrud and Stewart 1977) that have the greatest susceptibility to conversion and have experienced the greatest losses. The negative impacts of wetland loss on waterfowl and other wildlife is exacerbated by intensive agricultural land use that has reduced the amount and quality of adjacent upland grassland cover necessary for reproductive success.

The Prairie Pothole region supports approximately 50 percent of the U.S. production of migratory waterfowl but nest success has been low throughout much of this region due to high rates of predation and overall poor quality and quantity of nesting habitat (Cowardin et al. 1985). Limitations on waterfowl production have been characterized as severe in this region as a result of wetland losses, degradation of wetlands by agrichemicals, and intensive agricultural production (Grue et al. 1989).

Within the Central Plains, the Rainwater Basin in south central Nebraska provides essential habitat for 57 million migratory waterfowl as well as federally threatened and endangered species, e.g., whooping crane and piping plover (Department of the Interior 1988). The Rainwater Basin originally contained approximately 4,000 individual wetlands that occupied about 95,000 acres. Between the 1960's and 1980's shallower wetlands declined by 74 percent and deeper, more permanent wetlands were reduced by about 47 percent. The majority of wetland loss in this region was due to conversion of wetlands to cropland and use of the more permanent wetlands for irrigation return water. Virtually all remaining wetlands have been modified to some extent by agricultural land use. A major impact of wetland loss in this region is the concentration of migratory waterfowl on fewer wetlands which increases the incidence of disease. Since 1975, approximately 20,000 birds have died of avian cholera in the Rainwater Basin, a situation that is attributed to overcrowding on the few remaining wetlands.

The Lower Mississippi Alluvial Plain extends 600 miles from the confluence of the Mississippi and Ohio rivers in Illinois to New Orleans. Once dominated by extensive bottomland hardwood forests, this region represents one of the most important wetland regions for migrating waterfowl, critical habitat for overwintering waterfowl, and habitat for numerous other species of aquatic and terrestrial wildlife (Department of the Interior 1988). The quality of habitat within this region affects the physiological condition of wintering waterfowl and, ultimately, reproductive success on northern breeding grounds (Heitmeyer 1985, Reinecke et al. 1986). Flood control and drainage programs have contributed to wetland loss in this region, but conversion to agricultural production accounts for 96 percent of the land cleared and drained in the Alluvial Plain (Department of the Interior 1988). Nationwide, wetland losses have been approximately 50 percent. However, within the lower Mississippi valley 80 percent of the original wetlands have been eliminated. Much of this land, especially on higher elevation sites, is devoted to production of soybeans, cotton, and rice. Remaining lower elevation wetlands typically provide inferior habitat, and lower quality foods for migratory waterfowl compared to sites converted to agriculture (Fredrickson and Heitmeyer 1988). The habitat quality of many of the remaining wetlands has been diminished due to agrichemicals and siltation (Fish and Wildlife Service 1986).

The preceding discussion is by no means inclusive of all agricultural impacts to wetlands. Other geographic area of concern include the California Central Valley, playa lakes in the Southern High Plains, and Gulf Coast wetlands. The impacts of wetland conversion, sedimentation and nutrient/chemical input stemming from agriculture are substantial within these geographic regions as well (Department of the Interior 1988, Ducks Unlimited 1994).

Agricultural development is the most frequent cause of habitat loss or habitat alteration leading to classification of threatened or endangered species (Flather et al. 1994). The predominant reason for listing 256 of 667 species (38 percent) as threatened or endangered were the environmental impacts of agriculture. The percentage endangered/threatened species taxa affected by agricultural development are: amphibians 63 percent; clams 57 percent; birds 55 percent; fish 43 percent; crustaceans 40 percent; insects 36 percent; plants 32 percent;

reptiles 27 percent; and; mammals 23 percent. Wetland habitats support fewer threatened and endangered species than other terrestrial or aquatic environments. However, because wetlands are a comparatively rare habitat type, they support a disproportionately high number of listed species. Rangelands dominated by herbaceous vegetation support at least 10 percent of rangeland-associated threatened and endangered species.

Agriculturally associated changes that include channelization, elimination of grasslands, modifications in flow, diminished groundwater levels, water quality, and impoundments have affected aquatic habitats to the point of endangering segments of fish communities endemic to prairie ecosystems (Echelle et al. 1995, Rabeni 1996). In 1989, the American Fisheries Society classified 25 species of prairie fishes as endangered, threatened or of special concern (Williams et al. 1989). Currently, over one-third of all fish species endemic to prairie regions are of concern due to declining abundance and distribution (Rabeni 1996).

The environmental damages stemming from agricultural land use vary geographically. Consequently, specific geographical areas and issues require special attention. In 1995 the U.S. Congress Office of Technology Assessment initiated a study to identify areas where agriculture has had significant impacts on water quality, soil quality, wildlife habitat, range quality, and water conservation (U.S. Congress, Office of Technology Assessment 1995). Substantial overlap between soil quality, water quality, and wildlife habitat affected by agriculture were apparent. The overlap of geographic regions represent areas where the greatest environmental returns for conservation oriented tax expenditures could be realized. Regions of special concern based on agricultural impacts to wildlife included: (1) the midwestern Cornbelt States; (2) habitats for endangered species, regardless of geographic area; (3) the Prairie Pothole region; (4) National Grasslands; (5) the Southern Plains; (6) habitats associated with State and Federal wildlife management areas; (7) the Lower Mississippi Alluvial Valley; (8) the Platte River headwaters; (9) riparian zones nationwide; and (10) the Great Lakes drainage basin.

Air Quality

Air quality is a significant environmental concern in some areas of the United States. Crop production practices adversely affecting air quality are primarily tillage practices. Agricultural tillage is a major source of fugitive dust in specific regions of the country, such as the Great Lakes, Upper Midwest, Pacific Northwest and the Great Plains. Up to 50 percent of the contaminants entering the Chesapeake Bay are airborne and have come from outside the Chesapeake Bay watershed and airshed. More specifically, computer model calculations indicate that roughly 75 percent of nitrogen deposition from the air that lands inside the Bay watershed is from sources outside of the watershed. These sources of air pollution, both agriculturally and non-agriculturally related, may occur hundreds of miles from the Bay watershed (Blankenship 1995). In addition, stressors from these operations on human health are wind-blown dust particles. Particulate matter less than 10 micrometers in size (PM-10) are nearly invisible dust particles that can stay windborne for long periods of time and are transported great distances. These dust particles can create health problems, especially when

breathed into the lungs of people with respiratory problems.

Certain practices can be applied to the landscape to aid in reducing airborne dust particles. Windbreaks, wind fences, vegetative barriers and cover crops are some of the practices that can reduce wind speed and the potential for wind-blown dust particles. Conservation tillage is also effective in eliminating exposed soil particles to wind action.

CONCEPTUAL DIAGRAMS OF THE ACTIVITY-STRESSOR-EFFECT RELATIONSHIPS

Following the end of this section are the conceptual diagrams that delineate ecological pathways consisting of: (1) risk initiators (large rectangles in the diagrams and capital boldface letter headings in the text); (2) system stressors (ellipses in the diagrams and capital letter headings in the text); (3) ecological effects (small rectangles in the diagrams and capital and small characters in the boldface lettering in the text); and (4) assessment endpoints (hexagons in the diagrams and italics in the text).

SOIL AND LAND DISTURBANCE

Soil or land disturbance from crop production occurs primarily as a result of tillage activities that may be aggravated by natural forces, such as wind, rain, and drought, and major land use conversion activities, such as wetland drainage. The effects can be short- or long-term and affect the immediate or an off-site area.

Soil erosion and compaction are likely the most extensive forms of soil disturbance encountered when examining the effects to and from the agricultural systems being examined in this assessment. Physical alteration of the land such as drainage of wetlands and conversion to cropping uses can also have adverse impacts: increased flooding, reduced or altered habitats for wildlife, and deterioration in water quality.

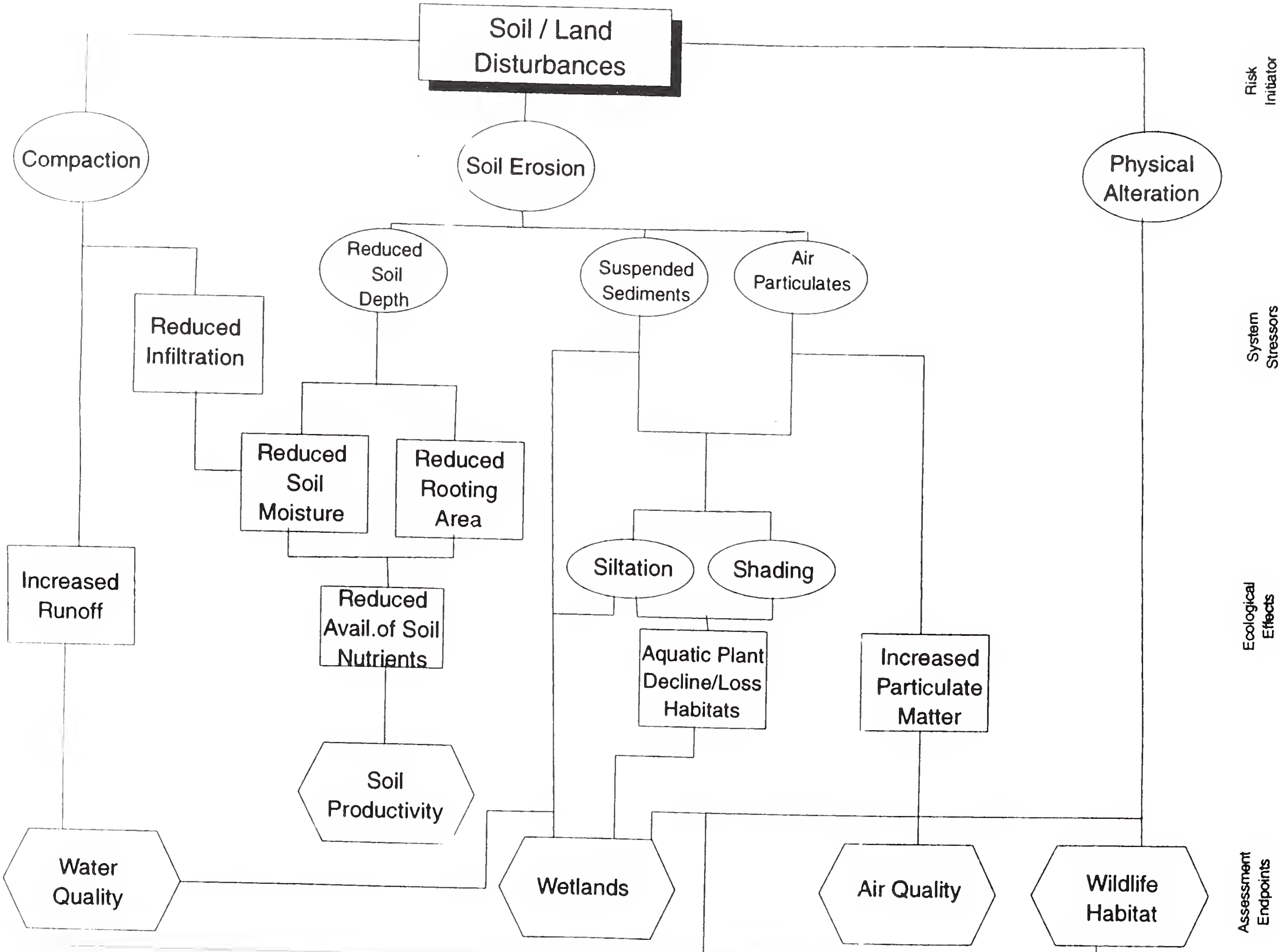
Figure 2.1 illustrates the relationship between soil and land disturbance activities, the stressors that can be created by such activities, and the effects of the stressors on the environment.

Ecological Summary

The following system stressors and ecological effects associated with soil/land disturbances (risk initiator) are generating adverse interactions and causing risk assessment endpoints to be ecologically degraded:

- Soil compaction (stressor)
- Reduced infiltration (ecological effect)
- Increased runoff (ecological effect)
- Reduced soil depth (ecological effect)

Figure 2.1


Soil / Land Disturbances
Compaction
Soil Erosion
Physical Alteration
Reduced Soil Depth
Suspended Sediments
Air Particulates
Reduced Infiltration
Reduced Soil Moisture
Reduced Rooting Area
Siltation
Shading
Increased Runoff
Reduced Avail.of Soil Nutrients
Aquatic Plant Decline/Loss Habitats
Increased Particulate Matter
Soil Productivity
Water Quality
Wetlands
Air Quality
Wildlife Habitat
Risk Initiator
System Stressors
Ecological Effects
Assessment Endpoints

- Reduced soil moisture (ecological effect)
- Reduced rooting area (ecological effect)
- Reduced availability of soil nutrients (ecological effect)
- Soil erosion (stressor)
- Suspended sediments (stressor)
- Siltation (stressor)
- Shading (stressor)
- Loss of habitat (ecological effect)
- Air particulates (stressor)
- Increased particulate matter (ecological effect)
- Physical alteration (stressor)

The following soil/land disturbances assessment endpoints are at risk ecologically:

- Soil productivity
- Wetlands
- Water quality
- Air quality
- Wildlife habitat

Discussion

Specific resource values that have been shown to be at risk in this assessment on soil/land disturbances are soil productivity, water quality, wildlife habitat, wetlands, and air quality.

As a grouping, wetlands constitute the most sensitive of habitats when it comes to environmental stressors. While wetlands have large capacities to absorb environmental impacts, once the capacity is exceeded there is little chance for recovery back to the original condition of the wetland. For the most part, ecological processes within wetlands are not reversible. Instead, what often happens is that a wetland reaches a new equilibrium.

For example, in examining the addition of sediment to a wetland, a wetland has certain bio/geologic capabilities to accept sediment loads while still maintaining all of its integrated functions to support and nourish living systems that depend on the wetland for food, shelter, and reproduction. In a well-functioning wetland system, inputs of sediment can enter with little or no change to the wetland itself.

Part of the reason that a wetland can accept nominal amounts of sediment without any change is that small amounts of sediment cover living plants and animals in the bottom of the wetland. While sediment can cause the benthic organisms to smother and die, the sediments also complete the covering process causing already dead organisms to decay at even lower levels. As this decay occurs, the sediments that had been added on top of the wetland begin to sink from their raised level back toward the original level of the wetland. In this way the

wetland maintains a relatively constant level over time even though sediment is constantly entering and becoming entrained in the wetland.

A wetland can become threatened by sediments when large volumes enter a wetland in very short periods of time. Then the natural bio/geologic processes are short circuited and natural processes cannot work. The wetland becomes degraded or may become completely nonfunctional.

Wetlands take on additional meaning when considered in the context of threatened and endangered species. As many as two-thirds of the plants and animals that are on the Federal or State threatened and endangered species lists have some part of their life cycle associated with wetlands, either for food, shelter, reproduction, or other functions. Thus, those impacts that adversely affect wetlands, also adversely affect threatened and endangered species. Less food produced by the wetland means less food for the threatened and endangered species in the wetland. Dead and dying plants, leaving bare areas, mean fewer nesting sites for birds. Conversely, overcrowding by overgrowth of a single plant species in degraded wetlands can mean abundant vegetative growth, but too thick for animals to penetrate and utilize the area, thereby reducing the wetland's available resources for the threatened and endangered species.

Land disturbances have both short-term and long-term implications for assessment endpoints. In the short-term, land disturbances, such as tillage, increase the amount of particulate matter in the air, especially PM-10 (particulate matter less than 10 microns in size). These small particles add to air quality problems and in some parts of the country, such as California's Central Valley and the Pacific Northwest, and can cause significant deterioration of air quality.

Soil/land disturbances can have profound ecological effects on plant yields. When soil becomes compacted, aeration of the soil to promote plant growth is inhibited and the soil becomes a hard surface which runoff waters can easily speed over, leaving the land dry, with receiving waters getting many of the nutrients that were intended for cultivated crops. Thus, the land has less nutrients and moisture to produce crops and receiving waters get extra amounts of nutrients that promote excessive aquatic plant growth. Ecologically, this represents a very adverse situation, where soil, water and organisms are all harmed at the same time.

Soil compaction has more direct consequences on the plants. Compaction, in addition to leading to increased runoff, decreases the moisture available to plants and reduces the area into which plant roots can expand. This condition, in combination with the conditions described previously, stunts plant growth even further and reduces plant productivity. With plant growth reduced, the adverse effects are transferred to the livestock and other animals that depend on those plants for their sustenance.

SOIL EROSION

Although erosion is a natural geologic process, it is often accelerated by cultivation. Soils are living, dynamic systems that are altered by changes in water content, temperature, and human activities. Following a disturbance, erosion can result in a variety of forms--gully, sheet, or rill--each having distinctive effects. Soil erosion can have on-farm or off-site effects. Generally, erosion from fields used for crops results in less high quality soil remaining for future production. On-site erosion damage can reduce the productivity of land, labor, and capital, and increase the need for chemical inputs. Erosion degrades soil condition by lowering organic-matter content, decreasing rooting depth, and decreasing available water capacity.

REDUCED SOIL DEPTH

Reduced soil depth leads to a decline in the ability of the remaining soil to hold moisture. Also, less area is available for root growth. Soils over bedrock or other impermeable barriers are more vulnerable to this stressor.

Reduced Soil Moisture and Reduced Rooting Area

Soil moisture and rooting areas are interrelated and are important aspects in maintaining plant growth. Roots need air, water, nutrients, and adequate space in which to develop. Changes in these attributes directly affect the health and productivity of the crop plant. The compound impact of adverse effects on these two factors is to reduce a plant's ability for growth by reducing the availability of soil nutrients.

Reduced Availability of Soil Nutrients

With reduced soil depth, moisture, and rooting area, nutrients normally available from the soil are lessened. Also, the soil's ability to receive nutrients from outside sources is diminished; sites with lower levels of biomass production capture and cycle the available nutrients less effectively than do sites with high levels of biomass production. A reduced nutrient storage capacity may lead to less efficient use of applied nutrients by crop plants and a greater potential for loss of nutrients to surface and groundwater.

SOIL PRODUCTIVITY

Some runoff and erosion is natural, but accelerated erosion on degraded land reduces the land's productive potential. Reduced soil depth inhibits plant growth and diminishes yields. The land may become too xeric for cropping. Soil erosion can thus change the kind and amount of vegetation the site can produce, perhaps even irreversibly.

SUSPENDED SEDIMENTS

Sediment is eroded soil that has been deposited into streams, rivers, drainage ways, and lakes. Depending on topography and hydrologic and climatic conditions, eroded soil may be loaded into streams or other water bodies. Sediment degrades water quality and often carries soil-absorbed chemicals and nutrients.

In aquatic systems, sediment can (1) increase turbidity, which causes decreased light for submerged vegetation, (2) increase water temperature, further disrupting the ecosystem and its plant and animal communities, and (3) when suspended, also inhibit respiratory functions in fish and hinder the hunting ability of site-dependent piscivores.

Nitrogen can be carried with sediments into water bodies. Excess nitrogen applications on cropland can lead to increases in the mass of residual nitrogen in the soil that is vulnerable to loss to the environment through surface runoff, leaching below the root zone, and volatilization into the atmosphere. Nitrate is soluble and mobile in water and is the form of nitrogen most commonly related to water quality problems.

Phosphorus is strongly bound to sediments by anion adsorption reactions. Most of the total phosphorus loss from cropped land is in the sediment-bound form. The potential for phosphorus delivery to surface waters varies widely among different agricultural practices; most of the phosphorus load to surface waters is due to row crops, particularly on fine-textured soils near watercourses.

Decreased soil erosion does not immediately translate into less suspended sediment in a stream. As the sediment load in runoff water from croplands decreases because of erosion control, the capacity of the cleaner water to pick up sediment in streambeds or stream banks increases. This process continues until the stream channel and the runoff water develop a new equilibrium between the sediment delivered in runoff water and the sediment stored in the stream channel.

SHADING AND SILTATION

Environmental factors that affect water clarity also affect submerged vegetation growth. The survival of aquatic vegetation depends on the amount of sunlight reaching the plants. Suspended sediments can detrimentally shade them from sunlight, inhibiting photosynthesis. Reduction of light is a primary cause of aquatic vegetation decline.

High levels of nutrients can stimulate the rapid growth of algae, known as blooms. Algal blooms cloud the water and reduce the amount of sunlight reaching vegetation. Certain types of algal grow directly on the plants, further reducing available sunlight.

Siltation of stream and lake beds can smother bottom-dwelling benthic organisms, such as insects, worms, shellfish, and fish.

Aquatic Plant Decline/Loss of Habitat

Aquatic vegetation must be supplied with a sufficient quantity of nutrients to grow and reproduce. Shading inhibits development of both new and existing plants, causing an overall decline in the plant community. Siltation can directly result in the killing of aquatic plants as well as inhibit growth. Some chemicals that are carried with sediments exacerbate the effect of sediments on aquatic habitats and may destroy fish spawning grounds.

The combined or individual impacts of shading and siltation results in the loss of lower trophic level food sources and habitat. Submerged vegetation is a valuable source of food, especially for waterfowl. Extensive loss of aquatic vegetation can force some species of waterfowl to migrate to other wintering areas or change their feeding habits.

WETLANDS (AND WILDLIFE HABITAT)

Wetlands function like natural sponges storing water and slowly releasing it. This reduces the likelihood of flood damage, prevents certain floods, and reduces flood heights. Wetlands also reduce water's erosive potential. Working like a filter, wetlands trap nutrients, sediments, and other materials from entering water bodies. As wetlands are filled with eroded soil, these functions are degraded. Although this is a natural process, it is accelerated by farming activities.

Loss of aquatic plants due to sediment, siltation, and shading, affects the entire ecosystem. The fish and other aquatic fauna or aquatic related animal and bird populations dependent on these food and habitat sources may decline, resulting in reduced food sources for higher trophic level piscivorous avian and mammalian species.

WATER QUALITY

Increased sedimentation reduces water quality by increasing turbidity and the concentration of nutrients and pesticides in the receiving waters. Increased nutrient and pesticide concentration can negatively affect the survival and growth of aquatic plant and animal species.

AIR PARTICULATES

When atmospheric conditions are favorable, wind passing over barren agricultural fields may cause soil erosion. This soil erosion by wind can damage plants through a sandblasting effect. Wind erosion in the United States moves about 2 billion tons of soil annually (USDA 1989).

The movement of soil by wind not only damages on-site soil productivity and crop production efficiency, but also degrades air quality by contributing to respiratory illnesses, impairing highway and airport visibility, and increasing cleaning and air purification costs in homes, offices and factories. A study in New Mexico (Huzar and Piper 1985), based on a survey of

households and businesses, found that substantial damages were experienced in the State every year from wind erosion. Based on the survey responses, the authors estimated that annual costs of about $466 million, or $3.00 per ton, resulted from wind blown sediments.

Another consideration is dust that can impair visibility. Several factors limit the size of dust suspended in the atmosphere. For example, the amount of dust released through wind erosion increases with the length of the field. Moreover, when the soil surface is damp, fine soil particles (potential dust) are bonded to other particles, and dust generation is very low. Under soil conditions wetter than the wilting point or air relative humidity greater than 98 percent, wind erosion and dust generation seldom occur. Since these conditions are often not present in the western United States, most wind erosion and dust generation occurs there.

Increased Particulate Matter

Of particular concern are very small airborne particles less than 0.00001 m in diameter, referred to as 10 microns, or PM-10, which have been shown to aggravate respiratory problems such as pneumoconiosis. Periods of soil erosion by wind from agricultural fields may increase the concentration of PM-10 in the atmosphere.

AIR QUALITY

Soil erosion may compromise air quality in some areas of the country. The generation of dust resulting from soil erosion by wind can impair visibility and damage crops. Damaged crops results in lower than expected yields. In some instances, very small dust particles aggravate respiratory problems in humans.

COMPACTION

Some crop management practices, such as excessive tillage and the use of heavy machinery, can compact the soil. This hampers the ability of the soil to receive water. Soil compaction impedes seedling emergence and decreases water infiltration, reducing the availability of nutrients for root uptake.

The physical structure, texture, and condition of the soil surface determine the portion of precipitation that runs off or infiltrates. In the process, the volume, energy, and timing of seasonal stream flows and recharge to groundwater are determined. Soil erosion and compaction degrade the capacities of watersheds to capture and store precipitation.

Reduced Infiltration

Compaction reduces infiltration of water into the soil profile, which translates into more runoff and less moisture available for plant use. Movement of water through soils to streams, lakes, and groundwater is an essential component of recharge and base flow in the hydrologic cycle.

Stream flow regimes are altered because of reduced infiltration: seasonal patterns of flow are exaggerated, increasing the frequency, severity, and unpredictability of high-flow periods and extending the duration of low-flow periods. Reduced water infiltration and water storage can reduce total vegetative biomass production and can result in shifts in species composition.

Increased Runoff

Normally, soil is able to absorb substantial moisture water, even during a heavy storm. But as a result of compaction, this function is compromised. More water runs off the soil surface instead of entering the soil profile to be stored for plant use or in aquifers. Increased runoff can also augment nonpoint source pollution because water is rushing over the land, accumulating soil particles, sediment, pesticides, and nutrients.

SOIL PRODUCTIVITY

Compaction of the soil reduces soil productivity by hampering the ability of seedlings to emerge and reducing the ability of the soil to receive water. The reduced water infiltration limits the ability of plants to utilize available nutrients.

WATER QUALITY

Because compaction limits the ability of water to infiltrate the soil, runoff increases and often augments water pollution by carrying additional amounts of soil particles, nutrients, and pesticides to receiving waters.

PHYSICAL ALTERATION

The physical alteration of land includes land use conversion (such as wetland drainage and/or cropping) or tillage. The physical alteration of land for conversion to cropping uses can have wide-ranging local effects on natural and related resources when done improperly or without prior site assessment.

WILDLIFE HABITAT

Wildlife habitat may be significantly altered or destroyed. The disturbance can remove habitat and reduce available food and water sources. This forces increased inter- and intra-species competition in areas where food, water, shelter, or nesting resources have been reduced or altered by the disturbance. Competition may ensue for any one of these resources, or for all of them, depending on the level of disturbance and species requirements.

Increased competition and less resources may affect threatened and endangered species more than other species. Threatened and endangered species are less able to adapt to quickly-changed surroundings, as their habitat requirements are often more specialized than other species. Because these species have been identified as threatened and endangered, their

populations are already depressed, and any further stress could be detrimental to species survival.

WETLANDS

Alterations or conversions can greatly reduce or eliminate the important environmental functions that wetlands perform. The types of impacts on wetlands resulting from conversions are similar to those discussed under soil erosion but become more severe as the extent of the alteration increases.

IRRIGATION

Irrigation is the artificial application of water on lands to assist in the growing of crops or pastures. Irrigation water is supplied from groundwater or surface water such as a stream, river, or lake.

There are four major irrigation methods:
1. Sprinkle - water is sprayed, or sprinkled, through the air to the ground surface.
2. Surface - water is distributed over the soil surface by gravity flow.
3. Micro - the frequent application of small quantities of water as drops, tiny streams, or miniature sprays through emitters or applicators placed along a water delivery line.
4. Subsurface - water is applied below the ground surface by raising the watertable to within or near the root zone.

The principal environmental issues relevant to irrigation are those concerned with the protection and management of water quality and soil productivity. Irrigated agriculture can result in water quality degradation through a concentrating process (transpiration and evaporation of water results in increasing the concentration of constituents in the remaining water), and a loading process (contaminants added to the return flow from soils and substrata). Pollutants from irrigated agriculture are sediment, total dissolved solids ("salinity"), trace elements, nutrients (phosphates and nitrates), and pesticides. Natural processes supply some of these pollutants. Separating irrigation impacts requires site specific data and intensive studies.

Water use for agricultural irrigation has created significant environmental impacts in some areas. Some of the major impacts, beneficial as well as adverse, are summarized as follows:

1. Seepage from both conveyance and on-farm distribution systems has created many diverse forms of fish and wildlife habitat. (Habitat impacts carry over to riparian ecosystems and affect small game, waterfowl, and other residents of these systems).

2. Seepage from irrigation conveyance systems and inefficient water use may increase recharge of aquifers.

3. Diversions from some streams have reduced available water supplies to a degree that has impaired aquatic communities and migration of anadromous fish.

4. Return flows from irrigated areas may contain biocide residues, nutrients, and sediment, and may reduce the quality of streams, lakes, or wetlands receiving the waters.

Basic principles of irrigation water diversions, application, and utilization need to be considered in relationship to the management of such water within a watershed or river basin. Figure 2.2 shows the relationship between irrigation water diversion and use, the stressors that can be created, and the impacts of the stressors on the environment.

Ecological Summary

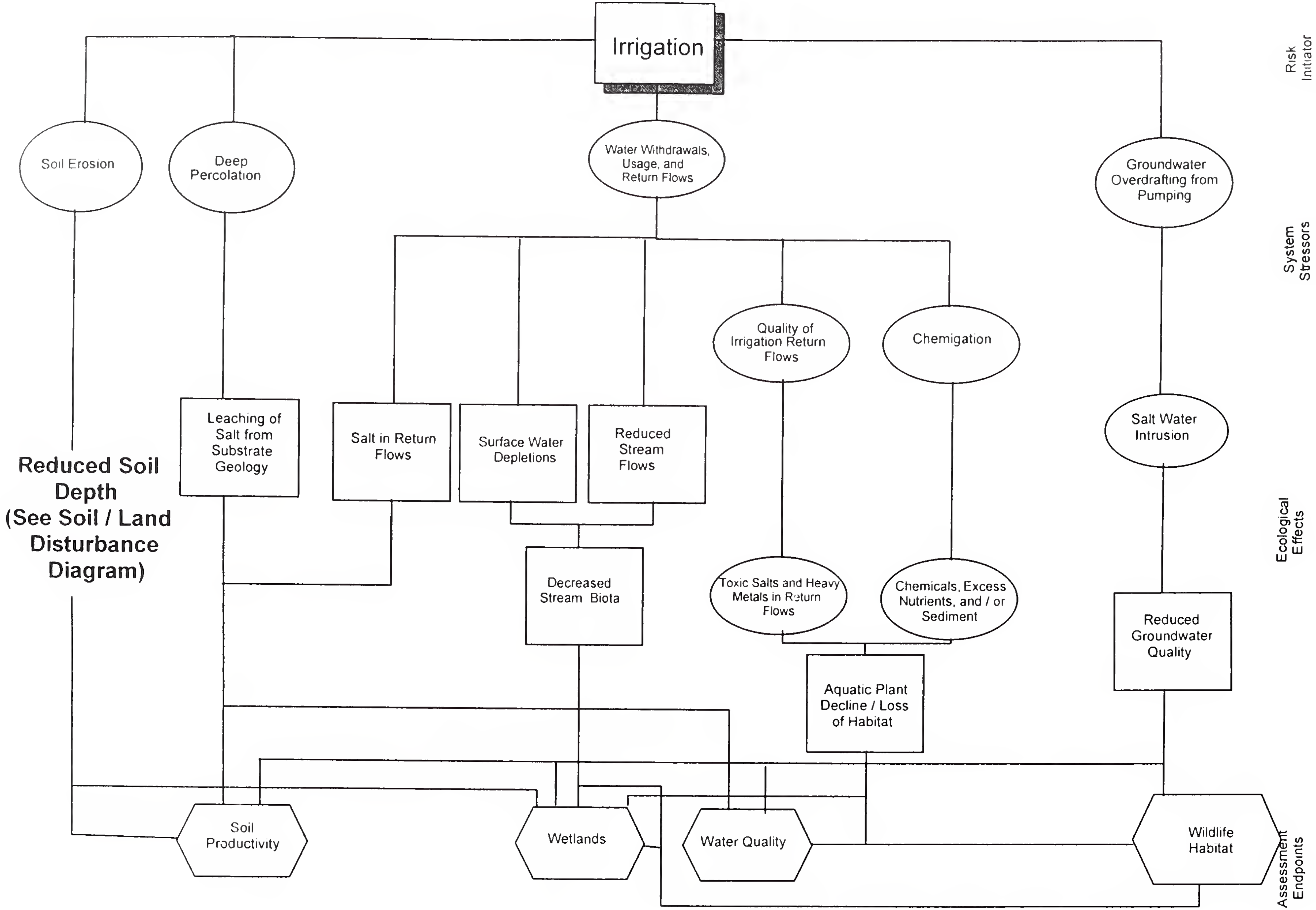
The following system stressors and ecological effects associated with irrigation applications are generating adverse environmental impacts and interactions and are causing risk assessment endpoints to be ecologically degraded:

- Soil erosion (stressor)
- Reduced soil depth (ecological effect)
- Reduced soil moisture (ecological effect)
- Reduced rooting area (ecological effect)
- Reduced availability of soil nutrients (ecological effect)
- Deep percolation (stressor)
- Leaching of salt from substrate geology (ecological effect)
- Water withdrawals, usage and return flows (stressor)
- Salt in return flow (ecological effect)
- Surface water depletions (ecological effect)
- Reduced stream flows (ecological effect)
- Decreased stream biota (ecological effect)
- Quality of irrigation return flows (stressor)
- Chemigation (stressor)
- Toxic salts and heavy metals in return flows (ecological effect)
- Chemicals, excess nutrients, and sediment (ecological effect)
- Aquatic plant decline/loss of habitat (ecological effect)
- Groundwater overdrafting from pumping (stressor)
- Salt water intrusion (stressor)
- Reduced groundwater quality (ecological effect)

The following irrigation applications assessment endpoints are at risk ecologically:

- Soil Productivity
- Water Quality
- Wildlife Habitat
- Wetlands

Figure 2 2


Irrigation
Risk Initiator
Soil Erosion
Deep Percolation
Water Withdrawals, Usage, and Return Flows
Groundwater Overdrafting from Pumping
System Stressors
Quality of Irrigation Return Flows
Chemigation
Leaching of Salt from Substrate Geology
Salt in Return Flows
Surface Water Depletions
Reduced Stream Flows
Salt Water Intrusion
Reduced Soil Depth (See Soil / Land Disturbance Diagram)
Ecological Effects
Decreased Stream Biota
Toxic Salts and Heavy Metals in Return Flows
Chemicals, Excess Nutrients, and / or Sediment
Reduced Groundwater Quality
Aquatic Plant Decline / Loss of Habitat
Soil Productivity
Wetlands
Water Quality
Wildlife Habitat
Assessment Endpoints

Discussion

Irrigation is a practice that has allowed humans to utilize areas that otherwise could not be agriculturally productive. The availability of adequate supplies of water allows farmers to grow crops in very dry regions of the country. However, this sometimes creates conditions that adversely affect the environment.

Because irrigation waters are often used over and over in a relatively small geographic area and time-frame, the possibility of contamination, especially from salts, becomes high. In addition to the constant recycling, the fact that many western States sit on geologic structures that are laden with salt deposits multiplies the potential for ecological problems.

In addition to the nutrients from chemical fertilizers, agricultural pesticides, and "natural" salts that irrigation waters pick up as they flow through cropland and the salt-laden geologic structures, other chemicals, such as heavy metals (e.g., selenium), become entrained in the water flow. These substances can have life-threatening effects on animals that drink the water. Also, the chemicals can reach healthy aquatic habitats and produce damage to aquatic plant and animal communities. For the aquatic communities, ecological decline and loss of viable habitats are inevitable. With the loss of aquatic communities, the life functions of threatened and endangered species cannot be supported. Keeping contaminated irrigation waters separate from potable drinking water supplies is a common problem when irrigation waters are integral parts of watersheds.

If irrigation waters are pumped via center-pivot irrigation systems or other large-scale pumping systems, thousands of gallons of water are sprayed onto fields each day. While recent innovations have reduced many of the older high-volume spraying operations, much water can be lost to evaporation or runoff if irrigation management is not carefully performed. These losses can ultimately adversely affect water supplies. Ecologically, large-scale pumping can lead to salt-water intrusion, thereby reducing groundwater quality.

WATER WITHDRAWALS, USAGE, AND RETURN FLOWS

To deliver a given amount of irrigation water to an irrigated crop, it is necessary to divert from the supply source amounts of water greater than that to be consumed by the crop. This diverted water may include the return flow of water previously used for irrigation in other areas.

Diverted water may leave the irrigated area as crop evapotranspiration, seepage from the conveyance system (canals and on-farm ditches), operational spills, deep percolation, tailwater runoff, evaporation, or as phreatophyte and hydrophyte consumption.

The water consumed by evapotranspiration from an irrigated crop is only slightly affected by the method or efficiency of irrigation, as long as the water available to the crop roots is not limited. Some of the problems resulting from ineffective use of irrigation water are caused by

the volume and timing of irrigation water pumped or diverted, relative to crop needs. Large withdrawals on some streams leave remaining in-stream flows inadequate for aquatic life, recreation, and water quality maintenance between the point of diversion and the areas of return flow from the irrigation.

SOIL EROSION

Sediment in irrigation return flows may cause water use impairment from sediment pollution and agrichemicals transported by sediment. This causes major water-quality degradation problems in several rivers in the western United States, harming fish and other aquatic life.

Erosion reduces the agricultural productivity of the fields and causes off-farm damages. In portions of southern Idaho, crop yield potential has been reduced by 25 percent due to 80 years of irrigation-induced erosion. Sedimentation effects in ditches and canals from irrigation induced erosion can be substantial.

DEEP PERCOLATION

Seepage varies depending on the condition of the canals and on-farm ditches. Piped or lined conduits have lower seepage amounts than unlined channels. Most seepage and deep percolation returns to natural stream channels either directly via drains, or indirectly through groundwater aquifers. Return flows reaching natural stream channels again become available for in stream use or downstream diversion. However, the return-flow water quality may be degraded. The recharge to aquifers also serves to maintain groundwater supplies, but may contaminate such waters in the process.

CHEMIGATION

Chemigation may be defined as the application of a chemical via an irrigation system by injecting the chemical into the water flowing through the system. Chemicals being applied by this technique include fertilizers, herbicides, insecticides, fungicides, nematicides, growth regulators, and biocontrol agents. Although chemigation has many advantages, potential risks from its use may include chemical back flow into the water supply; non-uniform chemical distribution; non-target chemical application as a result of drift, malfunctioning equipment, and runoff; and over or under application of the chemical.

GROUNDWATER OVERDRAFTING FROM PUMPING

The major impact of irrigation on groundwater aquifers in areas where the water is supplied from the aquifer results from the consumptive use for crop production or other purposes. In the shallow or moderately deep aquifers, most seepage and surface return flow will find its way back to the aquifer. Where water is pumped from deep aquifers, the time of return is slow and questionable. Therefore, the total withdrawal can be considered a depletion of the aquifer. Any reduction in withdrawal demands will prolong the life of these deep aquifers.

In areas where conjunctive use of surface and groundwater is practiced, or surface water is the primary supply, total withdrawals are expected to affect groundwater supplies only to the extent consumptive use exceeds the surface water supply.

When irrigation water is pumped from ground or surface water supplies, energy requirements are in direct proportion to the volume of water pumped. Thus, excess water applications increase energy use and require greater capacity of pumps, engines, and distribution conduits. In areas such as the Texas High Plains, where groundwater pumping exceeds the recharge rate of the aquifer, excess use of irrigation water decreases the useful life of the groundwater aquifer.

Seepage from irrigation conveyance systems and inefficient water use has increased recharge of aquifers. Diverted irrigation water that recharges a groundwater aquifer through seepage or deep percolation adds to the water supply available to groundwater users. Some farms and small communities depend on these replenished supplies. In some cases, aquifers are used to store and distribute temporary excess surface supplies.

SALT WATER INTRUSION

Water from wells is frequently contaminated by saltwater intrusion. The salinity of groundwater generally increases as depth increases. This phenomenon is related to the original deposition of the salt-bearing formations, the movement of groundwater, and the movement of individual ions over time. The salinity of groundwater is also traceable to other factors, such as proximity to oceans and leaching from surface sources.

The most frequent cause of saltwater intrusion is excessive pumping, or groundwater mining. Since irrigated agriculture is a heavy user and consumer of groundwater, it may contribute to saltwater intrusion in some locations.

Surface Water Depletion

Diversions from some streams have impaired aquatic communities and migration of anadromous fish.

In the western States, high early-season streamflows from snowmelt are diverted near the headwater. The entire diversion, irrigation, and return flow process may take from a few hours to a few months. The delays occur when a significant amount of flow returns through the groundwater system. These returns supplement the later season low flows that normally occur. The net effect is similar to reservoir storage. Thus, large increases in system efficiencies of "upstream" irrigation activities may require additional water storage to provide the same downstream water supplies later in the season.

With each diversion a portion of the water is permanently consumed through evapotranspiration of the irrigated crop. The net effect is a decrease (in some cases

substantial) in the total annual flow of the stream as it moves downstream.

TOXIC SALTS AND HEAVY METALS IN RETURN FLOWS

A small quantity of deep percolation (movement of water downward below root zone) is necessary to remove salts that would otherwise accumulate within the root zone, hampering and eventually prohibiting plant growth. This water is referred to as the leaching requirement and the quantity depends on soils, crops grown, climate, and water quality.

High concentrations of inorganic trace elements in irrigated soils and shallow groundwater pose a threat to agricultural production and the health of humans and animals, in three ways: (l) trace elements can accumulate in plants to levels that cause phytotoxicity; (2) trace elements in plants can adversely affect humans and animals that consume those plants; and (3) trace elements can migrate with seepage through the root zone and into groundwater, possibly re-emerging with the subsurface drainage in surface waters, thereby affecting wildlife, or with groundwater pumped for domestic use, thereby threatening the health of humans.

Salts in Return Flows

Salts are a product of the natural weathering process of soil and geologic material. They are present in varying degrees in all soils and in fresh water, coastal waters, estuarine waters, and groundwaters.

In soils that have poor subsurface drainage, high salt concentrations are created within the root zone where most water extraction occurs. The accumulation of soluble and exchangeable sodium leads to soil dispersion, structure breakdown, decreased infiltration, and possible toxicity. Thus, salts often become a serious problem on irrigated land, both for continued agricultural production and for water quality considerations. High salt concentrations in streams can harm freshwater aquatic plants just as excess soil salinity damages agricultural crops. While salts are generally a more significant pollutant for freshwater ecosystems than for saline ecosystems, they may also adversely affect anadromous fish. Although they live in coastal and estuarine waters most of their lives, anadromous fish depend on freshwater systems near the coast for crucial portions of their life cycles.

The movement and deposition of salts depend on the amount and distribution of rainfall and irrigation, the soil and underlying strata, evapotranspiration rates, and other environmental factors. In humid areas, dissolved mineral salts have been naturally leached from the soil and substrata by rainfall. In arid and semi-arid regions, salts have not been removed by natural leaching and are concentrated in the soil. Soluble salts in saline and sodic soils consist of calcium, magnesium, sodium potassium, carbonate, bicarbonate, sulfate, and chloride ions. They are fairly easily leached from the soil.

Irrigation water, whether from ground or surface water sources, has a natural base load of

dissolved mineral salts. As the water is consumed by plants or lost to the atmosphere by evaporation, the salts remain and become concentrated in the soil. This is referred to as the "concentrating effect."

The total salt load carried by irrigation return flows is the sum of the salt remaining in the applied water plus any salt picked up from the irrigated land. Irrigation return flows provide the means for conveying the salts to the receiving streams or groundwater reservoirs. If the amount of salt in the return flow is low in comparison with the total stream flow, water quality may not be degraded to the extent that use is impaired.

However, if the process of water diversion for irrigation and the return of saline drainage water is repeated many times along a stream or river, water quality will be progressively degraded for downstream irrigation use as well as the other uses.

Leaching of Salt from Subsurface Geology

Depending on geologic conditions, deep percolating water may slowly flow to deep aquifers or may enter stream systems through natural or manmade drainage systems. Deep percolation is often excessive as a result of poor irrigation management or nonuniform application inherent in many irrigation systems.

The deep percolating waters may come in contact with ancient lake and seabed deposits, picking up additional salts on the way back to groundwater or surface flows. There is also displacement and mixing of saline water in the underlying aquifer by deep percolating irrigation water.

Where deep percolating irrigation waters contact saline aquifers or geologic formations high in salt, the returning waters may have salt concentrations much higher than the originally diverted water.

QUALITY OF IRRIGATION RETURN FLOWS

Filling the root zone on graded irrigation systems results in tailwater runoff at the lower end of a farm field. The amount of runoff depends on soil conditions, irrigation system design, and water application methods. Some tailwater runoff may be unavoidable when graded surface irrigation systems are operated to achieve adequate infiltration and water application uniformity. Tailwater may evaporate, percolate, be consumed by phreatophytes, or reach stream channels as surface or groundwater return flow. Runoff may be collected on-farm and pumped back into the delivery system for reuse, or may be intercepted by other users as a supplemental or primary water source.

Surface runoff often carries sediments eroded from irrigation fields or drainage channels. The suspended sediment produces unfavorable conditions of aquatic life in receiving rivers and reservoirs.

Return flows to natural stream channels resulting from tailwater runoff, drainage flows, operational spills, or groundwater discharge may provide all or a portion of a downstream user's water supply. Return flows from irrigation sources often increase the sustained flow in smaller streams to the extent that the stream can support limited fisheries not otherwise available.

Reduced Stream Flows

Diverting less water for irrigation would generally not significantly change the water use on an irrigation project. Additional water would be available for nonconsumptive instream uses between the points of diversion and return flow. The water would only be available during the time the diversion would have been made, in the absence of reservoirs to store it.

Many irrigation projects have been developed, at least in part, with consideration of return flows and reuse. The streamflow in the lower reaches of most streams does not consist of new water, but of return flows of water previously diverted from the system in the upstream reaches. Thus, the system storage and return flow provided by current irrigation practices affects other water-related activities at downstream locations.

Decreased Stream Biota

A more accurate picture of the impact of irrigation can be presented by considering resident fish and anadromous fish separately.

Resident fish live their entire life spans in a local area (stream reach and/or reservoir). The well-being of stream fisheries is directly influenced by the instream flow conditions. Some species are intolerant of changes in their environment. Other species are very tolerant of such changes. Generally, the more desirable game fish species are less tolerant than the "rough" fish. Therefore, shifts in species composition have occurred and, depending on the local conditions, could be deemed either desirable or undesirable. Reservoir fisheries may benefit from water conservation measures that result in reducing reservoir drawdown and improving quality of return flows.

Anadromous fish spend a part of their lives in saltwater, but return to freshwater to reproduce. They are found in many of the tributary streams flowing into the Nation's coastal waters, but of primary importance are those streams tributary to the Pacific Ocean. Important anadromous fish include several salmon species, steelhead trout, smelt, sturgeon, and striped bass. Many of the streams in the mountain meadow, intermediate valley, and lower valley areas in California, Washington, Oregon, and Idaho provide the desired spawning, incubation, and rearing areas in addition to passageways for anadromous fish species. Reservoirs and irrigation water diversions have significantly contributed to changes of instream flows and the associated biota in waters tributary to the Pacific Ocean. In the mountain meadow setting of the Pacific Northwest, salmon and steelhead fingerlings and smolts may be diverted onto irrigated lands and perish if diverted water is not properly screened.

Water and power developments in California have had a significant impact upon migrations of salmon and steelhead smolts in addition to striped bass. Irrigation in the intermediate and lower valleys decreases instream flows for spawning, incubation, and rearing of juveniles at critical times. Decreased streamflows and increased pollutant loading from return flows from agriculture areas affect estuaries. A reduction of sedimentation and pesticide residues would greatly assist in sustaining, protecting, and perhaps perpetuating the biotic communities common to the estuarine environment. Maintenance of this estuarine habitat is critically important to anadromous fish. The potential increase in survival would provide beneficial impacts to the commercial and sport fishing industries. The increased survival would assist in the perpetuation of specific races of fish species, thus keeping them off the endangered and threatened species list.

SOIL PRODUCTIVITY

Salinity and excessive levels of heavy metals in irrigation water and irrigation-related erosion can decrease the productivity and quality of soils for agricultural crop production. The erosion impacts are the same as those described in the section on land disturbance/alteration.

WATER QUALITY

Introduction of excessive amounts of suspended sediment, nutrients, pesticides, salts, and heavy metals through irrigation can have significant adverse impacts on the aquatic plant and animal communities and the human uses of water for drinking, recreation and other purposes. The adverse impacts of excessive nutrient and pesticide levels will be described in the following sections. The impacts of sediments are discussed in the section on land disturbance/alteration.

WILDLIFE HABITAT

Cropland irrigation can have both negative and positive impacts on wildlife habitat. Waterfowl, shorebirds, herons, and other species dependent upon wetlands and seeps benefit from irrigation conveyance losses, tailwaters, and operational spills. However, irrigation activities also have negative impacts on wildlife. Diversion of water from streams for irrigation sometimes results in insufficient flow levels to support anadromons fish migrations and the life functions of other aquatic dependent plant, animal, and fish species. Also, contamination of irrigation water and return flows with sediments, nutrients, pesticides, salts and heavy metals can adversely impact the habitats and food sources of aquatic plant and animal communities.

WETLANDS

Many of the positive and negative impacts of cropland irrigation on wildlife habitat are also directly related to the wetlands that are enhanced or degraded by irrigation waters. Irrigation tailwater return flows or conveyance losses sometimes create or enhance wetland

environments. Other times, however, diversion of surface or groundwaters for irrigation purposes may create water shortages that degrade existing wetland. Further, excessive levels of sediment, nutrients salts, and chemicals in irrigation waters may fill the wetland, destroy the wetland vegetation, and greatly diminish the ability of the wetland to store and cleanse water and support water-dependent animal and plant communities.

PESTICIDE APPLICATION

Pesticide application includes the use of both herbicides for weed control and insecticides for pest control. Most compounds are broadcast by use of tractor mounted or towed spray equipment. However, some aircraft delivery of dry-form compounds occurs. Herbicides are the predominant pesticide, accounting for 85 percent, by volume, of the pesticides used on major field crops. Insecticides account for about 13 percent of total pesticide use on major field crops (USDA 1994). Highest levels of pesticide expenditures are in Florida, California, Washington, the Mississippi River Valley, and the Midwest.

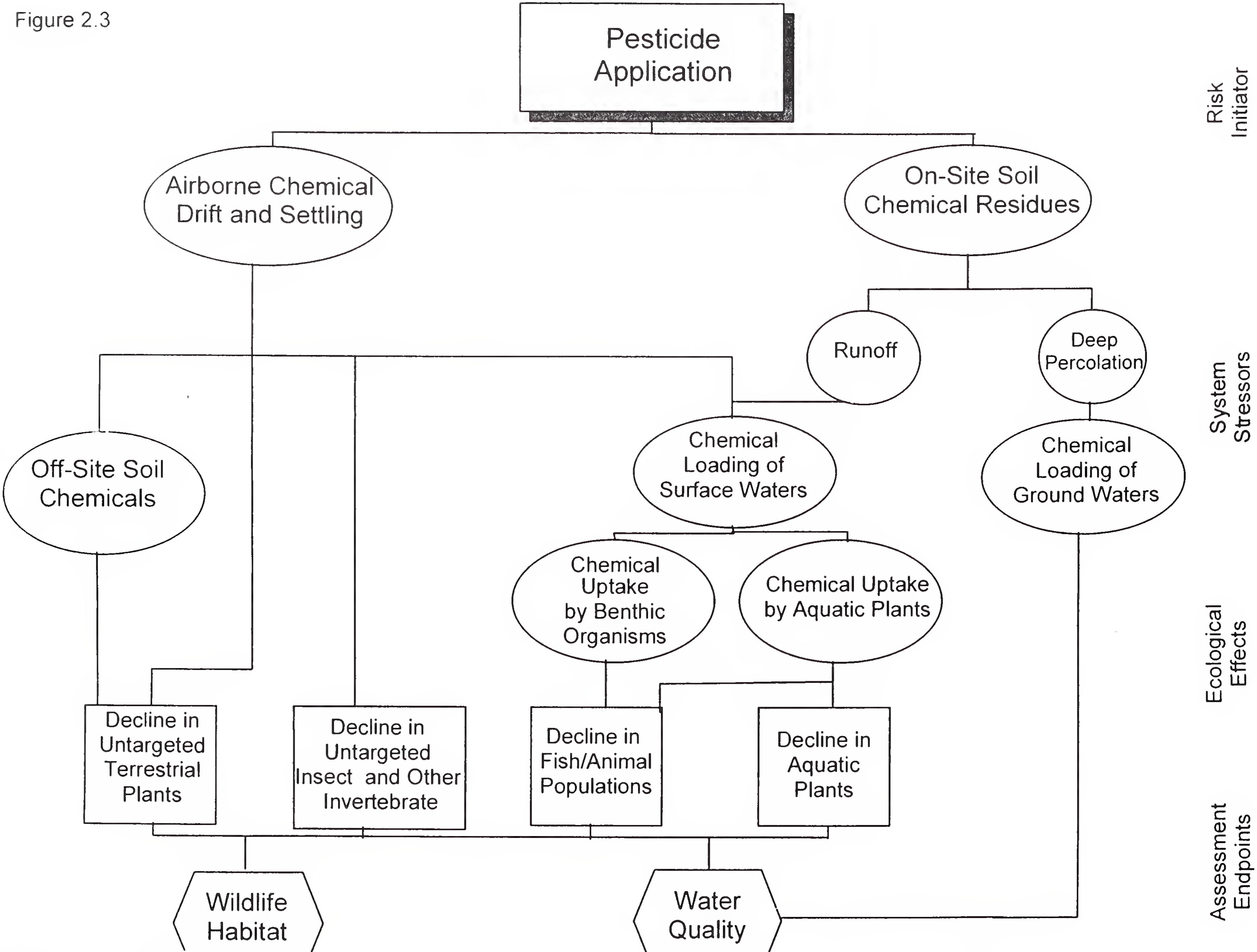
Once a pesticide is applied, the fate and transport of the compound are controlled by several processes. These include photo-decomposition, chemical degradation, biological degradation, volatilization, plant uptake and metabolism, adsorption to soil in run-off, and leaching. Microbial degradation is the most common route of pesticide degradation, and soil conditions that favor microbial activity can result in an increased rate of pesticide degradation. Adsorption is the binding of pesticides to soil particles and affects the potential movement of a pesticide to ground or surface water. Run-off is the surface movement of pesticides in water. Pesticides can move either dissolved in water or adsorbed to soil particles. Leaching is the movement of pesticides in water through soil and is dependent on pesticide properties and soil permeability. Deep percolation or run-off of pesticides require rainfall or irrigation. Tillage practices can influence both run-off and deep percolation.

Figure 2.3 illustrates the relationship between the application of pesticides on cropland,the stressors that can be created by this activity, and the effects of the stressors on the environment.

Ecological Summary

The following system stressors and ecological effects associated with pesticide applications are generating adverse environmental impacts and interactions and are causing risk assessment endpoints to be ecologically degraded:

Figure 2.3


Pesticide Application
Airborne Chemical Drift and Settling
On-Site Soil Chemical Residues
Runoff
Deep Percolation
Off-Site Soil Chemicals
Chemical Loading of Surface Waters
Chemical Loading of Ground Waters
Chemical Uptake by Benthic Organisms
Chemical Uptake by Aquatic Plants
Decline in Untargeted Terrestrial Plants
Decline in Untargeted Insect and Other Invertebrate
Decline in Fish/Animal Populations
Decline in Aquatic Plants
Wildlife Habitat
Water Quality
Risk Initiator
System Stressors
Ecological Effects
Assessment Endpoints

- Airborne chemical drift and settling (stressor)
- Off-site soil chemical residue (stressor)
- Decline in untargeted terrestrial plants (ecological effect)
- Decline in untargeted insect populations (ecological effect)
- On-site soil chemical residues (stressor)
- Runoff (stressor)
- Deep percolation (stressor)
- Chemical loading of surface waters (stressor)
- Chemical loading of groundwaters (stressor)
- Chemical uptake by benthic organisms (stressor)
- Chemical uptake by aquatic plants (stressor)
- Decline in fish and animal populations (ecological effect)
- Decline in aquatic plants (ecological effect)

The following pesticide applications assessment endpoints are at risk ecologically:

- Water Quality
- Wildlife Habitat

Discussion

The most significant environmental stressors in pesticide applications are the on-site use of chemicals and the off-site consequences to nearby land and water. Because pesticides must often be applied rapidly and in large quantities relative to the large acreages involved, a "shotgun" approach is often used, rather than a "surgical" approach. Airborne chemical applications are usually done with as much precision as the methodology allows, but the coverage is typically for the complete field and everything on it. Ecologically, it can affect the entire field even though the object of the application is a specific animal or plant target.

With a widespread broadcast, such as aerial application, airborne chemicals do drift off-site. Also, they can become entrained in runoff and move in the water to watercourses and water bodies. Chemicals that leave the field can have direct effects on human populations by contaminating drinking water supplies, either in wells or in reservoirs.

In extreme cases of chemicals reaching off-site areas, there can be uptake of the chemicals by organisms or plants directly causing fish kills or indirectly causing fish kills when aquatic vegetation dies creating deficits of dissolved oxygen. In other cases of chemicals escaping from fields where originally applied, there can be declines in untargeted terrestrial or aquatic plants and animals. Species populations can change and undesirable plants and animals can invade to occupy the empty niches that developed. This creates the need to use even more chemicals to control the undesirable, invading species. Ecologically, it can become an even more harmful situation.

AIRBORNE CHEMICAL DRIFT AND SETTLING

Aerosolized liquid and airborne dry compounds may drift from the application site to settle on off-site vegetation and surface water bodies. The fate of these compounds then depends on chemical structure and the material on which they settle.

OFF-SITE CHEMICAL RESIDUE

Depending on the stability of the class of pesticide used, accumulations of the compounds in off-site soils may lead to continual, long-term unintended adverse impacts on plant populations and biodiversity.

Decline in Terrestrial Plants

A decline and alteration of preferred specie terrestrial plant populations can occur as a result of chemical residues in off-site soils from settling of aerosolized particles or from chemical leaching from on-site soils via run-off. Alterations in terrestrial plant populations may impact mammalian and avian wildlife through a decline in available vegetative food stuffs or a loss of appropriate nesting materials or habitat.

Decline in Untargeted Insect Populations

Insecticides, in general, are broad-spectrum and impact both targeted and non-targeted insect species. Non-target species may be affected both on-site during proper application of chemicals and off-site as a result of drift and wind currents. Many insect species are critical to the ecosystem, providing pollination for plant communities and food source for avian and mammalian wildlife.

ON-SITE CHEMICAL RESIDUE

The fate of pesticides applied to a field depends on the intrinsic quality of the soil, the class of pesticide, and anthropogenic activity factors. Pesticides may leave the site through several methods. Depending on the properties of the pesticide and the soil type, there is the potential for some pesticide loss past the root zone. If this occurs, pesticides may leach into groundwater through percolation. Surface residues of the pesticide may be subject to direct run-off during application or after application via irrigation activities or natural weather conditions. In the case of pesticides tightly bound to surface soils, soil erosion can provide a mechanism for pesticide loss. These particles contribute to chemical loading in surface water bodies.

CHEMICAL LOADING OF GROUNDWATERS

Groundwater may become contaminated as a result of percolation of pesticide in solution past the root zone and impact groundwater. EPA estimates that about 10 percent of the Nation's

community water system wells and about 4 percent of the Nation's rural domestic wells contain at least one pesticide. However, no community water system wells and less than 1 percent of the rural domestic wells have pesticide levels exceeding EPA standards for drinking water (USDA 1994).

CHEMICAL LOADING OF SURFACE WATERS

As noted above, pesticides can become loaded into surface water as a result of intrinsic soil and pesticide properties and from various application practices. Based on the chemical properties of the compounds, pesticides may be found in surface water in solution in the water column or bound to organic carbon in sediments. Sediments with high organic carbon levels will bind high levels of pesticides. Bound to sediments in this way, pesticides may be persistent in the environment and remain in the water body for a long time. Pesticides in solution in the water column will be transported with the natural flow of the system and may leave the immediate environment but impact agricultural and natural ecosystems downstream.

UPTAKE BY BENTHIC ORGANISMS

Benthic organisms, including shellfish, feed by filtering sediments. In this way, these organisms can ingest pesticides. Ingested pesticides may have direct toxic effects resulting in die-off of the community or be taken up and accumulated in the tissues of these organisms. Many of these organisms provide a common food source for higher trophic levels in the food chain, including fish, terrestrial mammals, birds, and humans.

Decline in Fish Populations

Similar to the effects in benthic organisms, bottom-feeding fish may ingest sediment bound pesticides. The effects may be direct toxicity or uptake and accumulation in fish tissues. Fish species feeding on benthic organisms which have ingested sediment-bound pesticides may suffer direct toxic effects or further accumulate and concentrate pesticides, with the potential to pass them on to higher trophic level species. Column feeding fish may also ingest suspended pesticides with direct toxic or tissue uptake results.

UPTAKE BY AQUATIC PLANTS

The potential impacts of bound or suspended pesticides on aquatic plants are similar to those on benthic organisms. Pesticides may be directly toxic to plants or may be taken up by the plant and passed on to other members of the food chain.

Decline in Aquatic Plants

Direct toxic effects in plants resulting in vegetation die-off directly impact the organisms or species dependent on those plants for food or habitat, such as shellfish. Terrestrial mammalian

and avian species feeding on aquatic plants which have taken up pesticides may be directly affected or, in turn, take up and concentrate the chemicals in their body tissues.

WATER QUALITY

Application of pesticides on cropland can contaminate surface waters through direct contact from spills or drifts and through runoff from natural precipitation or irrigation waters. The pesticides can be in solution or attached to eroded soil particles. Groundwater contamination can occur if pesticides in solution percolate below the crop root zone.

Pesticides in water can adversely affect plants and animals resident in aquatic environments and animals, including humans, that ingest water. In extreme cases, ingestion can have direct toxic effects and the affected plant and animal communities may die off. More commonly, however, pesticides in water are taken up by aquatic plants and animals and stored in their tissues. If the organisms are part of a food chain, the pesticide may be taken up into the tissues of higher level organisms. Once taken into body tissues, the impacts of pesticides are quite variable, ranging from no effects to significant impacts on major life functions, such as reproduction.

WILDLIFE HABITAT

The impacts of pesticides on wildlife and their habitat are directly analogous to those for water quality. In extreme cases, pesticides can be directly toxic to wildlife species, the vegetative habitat in which they reside, or their food sources. More commonly, however, agricultural pesticides become embedded in the tissues of wildlife and their food sources. Increasing concentration in the body can lead to health and reproduction problems.

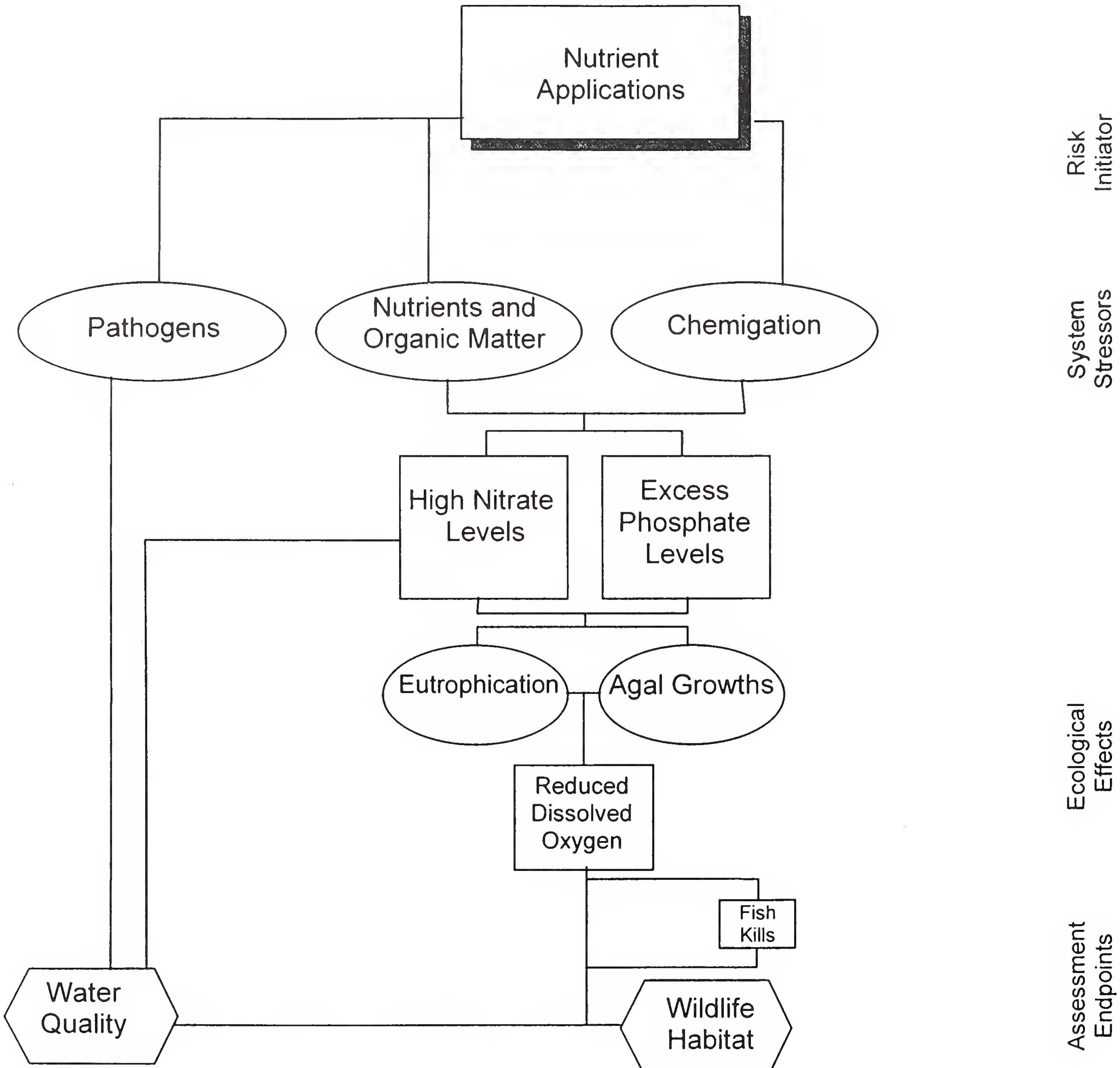
NUTRIENT APPLICATIONS

Agricultural land fertilization practices include the use of both commercially produced fertilizers (primarily nitrogen, phosphorus, and potassium), as well as the utilization of animal waste products (manures, bedding, and composted dead animals). Inappropriate application of commercial and animal component fertilizers, or the lack of sufficient land area on which to dispose of the nutrients derived from animal production, places various stressors on the environment.

Nutrients, including nitrates and phosphates from agricultural and nonagricultural sources, are the second leading cause of impairment in rivers, streams, lakes, and reservoirs and the primary cause in estuaries, according to surface water assessments performed by the States in 1990 and 1991 (USDA 1996b).

Figure 2.4 shows the relationships between the application of nutrients on cropland, the stressors created by these applications, and the impacts on the environment.

Figure 2.4


Nutrient Applications
Pathogens
Nutrients and Organic Matter
Chemigation
High Nitrate Levels
Excess Phosphate Levels
Eutrophication
Agal Growths
Reduced Dissolved Oxygen
Fish Kills
Water Quality
Wildlife Habitat
Risk Initiator
System Stressors
Ecological Effects
Assessment Endpoints

Ecological Summary

The following system stressors and ecological effects associated with nutrient applications are generating adverse environmental impacts and interactions and are causing risk assessment endpoints to be ecologically degraded:

- Pathogenic bacteria (stressor)
- Nutrients and organic matter (stressor)
- Chemigation (stressor)
- High nitrate levels (ecological effect)
- High phosphate levels (ecological effect)
- Eutrophication (stressor)
- Algal growths (stressor)
- Reduced dissolved oxygen (ecological effect)
- Fish kills (ecological effect)

The following Nutrient Applications Assessment Endpoints are at risk ecologically:

- Water Quality
- Wildlife Habitat

Discussion

In many respects, the ecological assessment endpoints that are at risk with pesticides are at risk with nutrients, i.e., potable water supplies and aquatic, terrestrial, and avian communities, including threatened and endangered species. Physically, the mechanisms of nutrients, including those from animal manures leaving fields, are similar to those of pesticides, except that nutrients are not aerially sprayed. Thus, many of the ecological impacts of nutrient applications are quite similar to those described in the pesticide application section.

When nutrients, such as nitrates and phosphates, leave the field via runoff to watercourses and water bodies, they can rapidly increase algal growths and the rates of eutrophication. The resulting low levels of dissolved oxygen can lead to fish kills or damage to aquatic communities. Ecologically, all natural processes become accelerated.

The ecological damage to potable water supplies, aquatic communities (including wetlands), and threatened and endangered species, is significant. Plants and animals are displaced from the normal niches and replaced by undesirable species.

PATHOGENS

The excreta from warm-blooded animals contain countless micro-organisms, including bacteria, viruses, parasites, and fungi. Some of the organisms are pathogenic (disease causing), and many of the diseases carried by animals are transmittable to humans. Human

exposure to pathogens may occur as the result of direct contact with manure that is handled or spread on cropland, but it is more likely that exposure results from pathogens delivered to a water system as a result of runoff.

NUTRIENTS AND ORGANIC MATTER

The major nutrients that pose a risk to the environment are nitrogen and phosphorus, including the organic nitrogen and phosphorus from animal wastes. Nitrogen continually cycles among plants, soils, water and the atmosphere, while phosphorus is less readily available due to adhesion to the clay particles of soil, moving into water bodies through sedimentation and siltation.

While nutrients affect the quality of both groundwater and surface water, organic matter contained in animal manure primarily affects surface waters. Organic matter, which is contained in large quantities in most types of animal manure is delivered to surface waters either through direct spillage or through rainfall/runoff mechanisms. Once in the water body, the organic matter creates a demand for dissolved oxygen as part of the decomposition process. This results in less available dissolved oxygen for aquatic life and, in severe cases (high concentrations of organic matter), fish kills and death of other aquatic organisms. Catastrophic events, such as accidental spillage of large volumes, or failure of manure storage facilities may directly smother or suffocate organisms and have long-term negative effects.

CHEMIGATION

Chemigation is the process of application of chemicals in an irrigation system and use of the irrigation system to convey the chemical to the crop. Fertigation, which is the application of fertilizer (nutrients) through use of the irrigation system, is a subset of chemigation.

Theoretically, use of fertigation allows nutrients to be provided to the crop as needed, thereby reducing the potential for nutrients to be leached out of the root zone. However, situations may arise which would reduce the apparent application efficiency of the irrigation system. For example, a fertigation cycle may be necessary during a period when rainfall provides sufficient water to meet the evapotranspiration requirements of the crop. Thus, the irrigation system is operated solely to transport nutrients to the crop. If the soil is saturated, or nearly so, there is increased potential for loss of nutrients. Once nutrients have been delivered to the cropland, the mechanism of transport and translocation is the same as for nutrients applied in the manner described above.

High Nitrate Levels

Nitrogen, in various chemical compounds, is applied to cropland in the form of commercial fertilizer and manure, to promote vigorous and healthy growth of plants. An essential plant nutrient, nitrogen continually cycles among plants, soil, water, and the atmosphere. Throughout this cycle, nitrogen undergoes complex biochemical transformation to nitrate, a

water soluble form that is easily absorbed by plant roots. Excess nitrates can run off and leach through the soil, potentially polluting both ground and surface water. EPA has established a water quality standard of 10 milligrams per liter (mg/l) of nitrate for drinking water. While this level is rarely exceeded in public water supplies on a large scale, there are locations around the country with large concentrations of livestock and sensitive geologic formations, such as karst (limestone) topography, which do exceed this level.

Excess Phosphate Levels

Phosphorus is an essential element for plant growth and increased crop yields. However, because soil phosphorus is commonly immobilized in forms unavailable for crop uptake, phosphorus amendments--mineral fertilizer or animal manure--are needed to achieve desired crop yields. Despite its benefit to crop production, phosphorus becomes a pollutant when it enters surface water in substantial amounts (USDA 1996b).

Excessive phosphorus concentrations in surface water can accelerate eutrophication, resulting in increased growth of undesirable algae and aquatic weeds. This growth can impair water use for industry, recreation, drinking, and fisheries. Although nitrogen and carbon are also associated with accelerated eutrophication, most attention has focused on phosphorus as the major contributing stressor element. Because it is difficult to control the exchange of nitrogen and carbon between the atmosphere and a water body and because of the fixation of atmospheric nitrogen by some blue-green algae, phosphorus control is seen as the primary way to reduce the accelerated eutrophication of surface water. Because phosphorus is not as soluble as nitrogen, it is less a problem to groundwater (USDA 1996b).

EUTROPHICATION

Water bodies need a certain amount of nutrients and minerals in order to support aquatic organisms. However, an excessive amount of nutrients results in an oxygen deficiency situation commonly known as eutrophication. Excess levels of nitrates in surface waters contribute to eutrophication and excessive growth of aquatic plants, leading to secondary effects such as odors and reductions in dissolved oxygen for fish and other aquatic organisms. Excessive contributions of phosphorus in surface water accelerates the eutrophication process. Phosphorus from animal manures can be significant, especially in situations where they are applied in extremely large amounts or at the wrong time. This is due, in part, to the practice of applying animal manures based on nitrogen management and crop nitrogen requirements instead of soil phosphorus requirements.

ALGAL GROWTH

Growth of algae is stimulated by the addition of excess nutrients, particularly nitrogen and phosphorus, to surface waters. When phosphorus enters the freshwater environment, it can produce nuisance growths of algae and aquatic weeds and can accelerate the aging process in lakes. Direct toxicity to fish and other aquatic organisms is not a major concern. However,

fish kills and reduced fish populations can be related to resulting reduced levels of dissolved oxygen in the water. Dissolved oxygen levels are reduced as oxygen is used for the decomposition process of the excess biomass (algae and other aquatic plants) that is stimulated by the excess nutrients. Algae may also have impacts on water temperature (generally warming), thereby changing the makeup of the aquatic community.

Reduced Dissolved Oxygen

Reduced oxygen levels result from excessive oxygen demand for the decomposition of organic matter contained in the water body. Organic matter from agricultural operations generally reaches a stream or lake in two ways. First, there is direct delivery of organic matter contained in manure through rainfall/runoff processes. Second, organic matter may result from decaying aquatic plants the growth of which was stimulated by delivery of excess nutrients, again through rainfall/runoff processes.

In a natural environment the breakdown of organic matter is a function of complex, interrelated, and mixed biological populations. The organisms principally responsible for the decomposition process are bacteria. If a large amount of organic matter, such as manure, is added to a water body, the bacterial population begins to grow, with the rate of growth expanding rapidly. Because each bacterium extracts dissolved oxygen from the water to survive, the addition of waste and the subsequent rapid increase in the bacterial population could result in a drastic reduction in dissolved oxygen in a stream or lake.

Fish Kills

An adequate supply of dissolved oxygen is essential for good fish production. Adding wastes to a stream can lower oxygen levels to such an extent that fish and other aquatic life are forced to migrate from the polluted area or die for lack of oxygen.

WATER QUALITY

Application of chemical fertilizers and animal wastes from cropland can adversely affect water quality through the introduction of excessive amounts of nitrogen, phosphorous, and pathogens. These are usually introduced to surface water through runoff of precipitation or irrigation water. Introduction to groundwater sources occurs through percolation of nutrients in solution below the root zone. Exposure to pathogens through contaminated water can lead to disease in humans and animals.

Excessive amounts of nitrogen and phosphorous in water bodies from chemical fertilizers and animal wastes rapidly expands growth of aquatic plants, including algaes, and may result in the introduction of new, less desirable plants and animals. After these plants die, the decomposition results in less available dissolved oxygen in the water, killing fish, and other aquatic animals and plants.

Excessive nitrates from nitrogen applications leach through the soil profile into the groundwater supplies. Occasionally, the levels of nitrates can be sufficiently high in wells to create a moderate health hazard for humans.

WILDLIFE HABITAT

The adverse impacts of nutrient applications on wildlife habitats relate primarily to the impacts on water quality--that is, the eutrophication of lakes and streams, the associated losses of aquatic flora and fauna, and the consequent negative effects of food supply reductions on larger predator species. An additional potential adverse impact is the introduction of new and less desirable plant and animal species and loss of preferred species.

III. ANALYSIS OF ECOLOGICAL EFFECTS

INTRODUCTION

The purpose of this section is to present an empirical description of the relationships between activities undertaken to produce food and fiber on U.S. cropland (i.e., stressors created and adverse ecological effects produced) and the resource protection requirements, ecological endpoints, of the CRP. The discussion of the relationships in the previous chapter involved a description of the cropping activities that, when combined with natural factors (weather, climate, soil and topographical conditions), created environmental stressors adversely affecting resource values protected by CRP. (These relationships are summarized in the conceptual flow charts presented in the previous chapter.)

In this section, the discussion is organized in a reverse order compared with the discussion in the problem formulation section. The narrative begins with a description of the assessment endpoints and ecological effects and then traces back to identify, to the extent possible, the production activities and stressors. In many instances, consistent and detailed empirical evidence is not available to define and describe the resource conditions or relationships.

As indicated in the previous chapters, CRP is directed primarily toward addressing the problems associated with production on cropland. Cropland is defined as land that is irrigated or non-irrigated, and cultivated or not cultivated for the purposes of producing agricultural commodities. According to USDA (1995) there are about 382 million acres of cropland in the United States. About 326 million acres are cultivated--278 million acres are non-irrigated and 48 million acres are irrigated. Nearly 57 million acres are not cultivated (primarily permanent hay)--42 million acres of which are not irrigated and 15 million acres are irrigated.

The primary adverse effects, or risks, to natural resources associated with agricultural production activities on cropland include the following: (1) classic sheet, rill, gully, and scour erosion that results in sediment deposition to streams, lakes, wetlands, and riparian areas, (2) soil compaction and decreased vegetation, resulting in increased runoff to streams and lakes, and reduced recharge of groundwater, (3) suspended sediments, turbid water, surface water contamination, and increased water temperatures that affect habitats of wild and domestic animals and plants, including threatened and endangered species, (4) decreased plant health and vigor, (5) reduced capacity of soils to grow and sustain plant life, (6) increased contamination of surface and groundwater supplies with nutrients, chemicals, and salts, (7) physical conversion of "natural" lands, especially wetlands, to cropping uses and the consequent loss in wildlife habitats, biodiversity, and wetland functions and values, and (8) wind erosion producing airborne soil particles that affect water quality and human health and safety.

The continued sustainability and productivity of cropland resources are necessary for the United States to have a reliable and economical food supply in the future. However, the production activities that occur on this cropland cannot be separated from the surrounding

environment. As described in the previous chapter, the major activities used to produce crops that adversely affect the environment include tillage or land disturbance practices, irrigation water applications, nutrient and pesticide applications, and drainage practices and other land use conversions.

These actions, in conjunction with the natural effects of wind, water, and temperature, give rise to the major areas of concern described in this chapter: soil erosion and the impact on the quality or productivity of the land, water quality, and wetland integrity; water quality impairment; wildlife habitat degradation; wetland function and value loss; and reductions in air quality.

SOIL EROSION

Erosion was estimated by the 1992 NRI to occur at the rate of 2.14 billion tons in the United States in 1992. This is a one-third reduction from the 1982 level. Almost all of the soil savings has taken place on cultivated cropland. Average erosion per acre has been reduced on cultivated cropland by about 1.8 tons per acre per year, or 590 million tons per year. Cultivated cropland acreage has fallen by 40.7 million acres since 1982, which has reduced erosion on cropland by about 410 million tons per year. About 90 percent of the reduction in acreage in cultivated cropland is due to enrollment in the CRP.

The major water erosion processes are sheet and rill erosion, ephemeral erosion, gully erosion, and scour erosion. Sheet and rill erosion is caused by broad water movement off fields during rain storms and is estimated to move 1.2 billion tons of soil per year. Ephemeral, small gully, and gully erosion result from concentrated storm water movement across fields during rain storms. Scour erosion occurs when streams leave their banks and severely erode land on the edges of the stream or floodplain. Ephemeral, gully, and scour erosion move large quantities of soil from concentrated areas. Unfortunately, there are no national estimates of the amount of soil removed from cropland by these processes. Wind erosion occurs when the wind picks up soil as it moves across fields. In 1992, wind erosion was estimated to have moved 930 million tons of soil.

Soil erosion that exceeds the rate of soil formation eventually reduces productivity. The reduction may be difficult to observe if the topsoil is deep. Excessive erosion may reduce crop yields to the point that continued production is infeasible, forcing the grower to retire the land to pasture or some other lower valued use. Permanent productivity reduction can significantly alter the climax vegetation even if the land is removed from agricultural production.

According to the NRI, sheet and rill erosion averaged 3.1 t/ac/yr in 1992, while wind erosion averaged 2.5 t/ac/yr. If it is assumed that crops would have been produced and conservation plans implemented on lands that were enrolled in the CRP in 1992, then total sheet and rill and wind erosion on cultivated cropland (including CRP) would have been about 1.2 billion tons and 0.9 billion tons, respectively. Areas with the greatest amount of sheet and rill

erosion are the Corn Belt and along the Mississippi River (Figure 3.1). The most wind erosion occurs further west, including western Texas, Oklahoma, and Kansas, and eastern Colorado (Figure 3.2). High wind erosion also occurs in western Minnesota and northwestern Iowa, eastern Washington, Southern Idaho, and Montana.

The maximum erosion rate that can occur while allowing a soil to indefinitely sustain a high level of crop production is called the "T", or soil loss tolerance, value. Erosion above T ultimately reduces the productivity of the soil. The T value for 71 percent of the Nation's cropland is 5 tons per acre per year (t/ac/yr). Soils can have a T value as low as 1 t/ac/yr.

Without enrollment of acreage in CRP, about 145 million acres would have eroded in excess of T, and of the 2.14 billion tons of soil that would have eroded about 1.1 billion would have exceeded the sustainable T rate. Geographically, the areas with highest incidence and levels of excess erosion correspond directly with the areas with the highest overall levels of water- and wind-related erosion (Figures 3.3 and 3.4).

With CRP enrollment, over one-third of the United States cropland, 131 million acres, is eroding at an average annual rate greater than T (Table 3.1). Almost half of the cropland in the Mountain region is eroding greater than T. The Lake States and the Southern Plains also have a disproportionately high percentage of cropland eroding greater than T. All the production regions have at least a quarter of their cropland soils eroding at a rate greater than T.

The propensity of cropland to erode can be characterized by the Erodibility Index (EI), which is based on climate, soil characteristics, and topography of a field. The higher the EI, the greater investment in soil conservation required to maintain the sustainability of the soil resource base if intensively cropped. Cropland with EI values above 8 is considered highly erodible because it generally requires a combination of at least 50 percent cover of crop residue, contouring, terraces, contour strip-cropping, and sod-based crop rotations to reduce erosion to the level that will sustain crop production indefinitely.

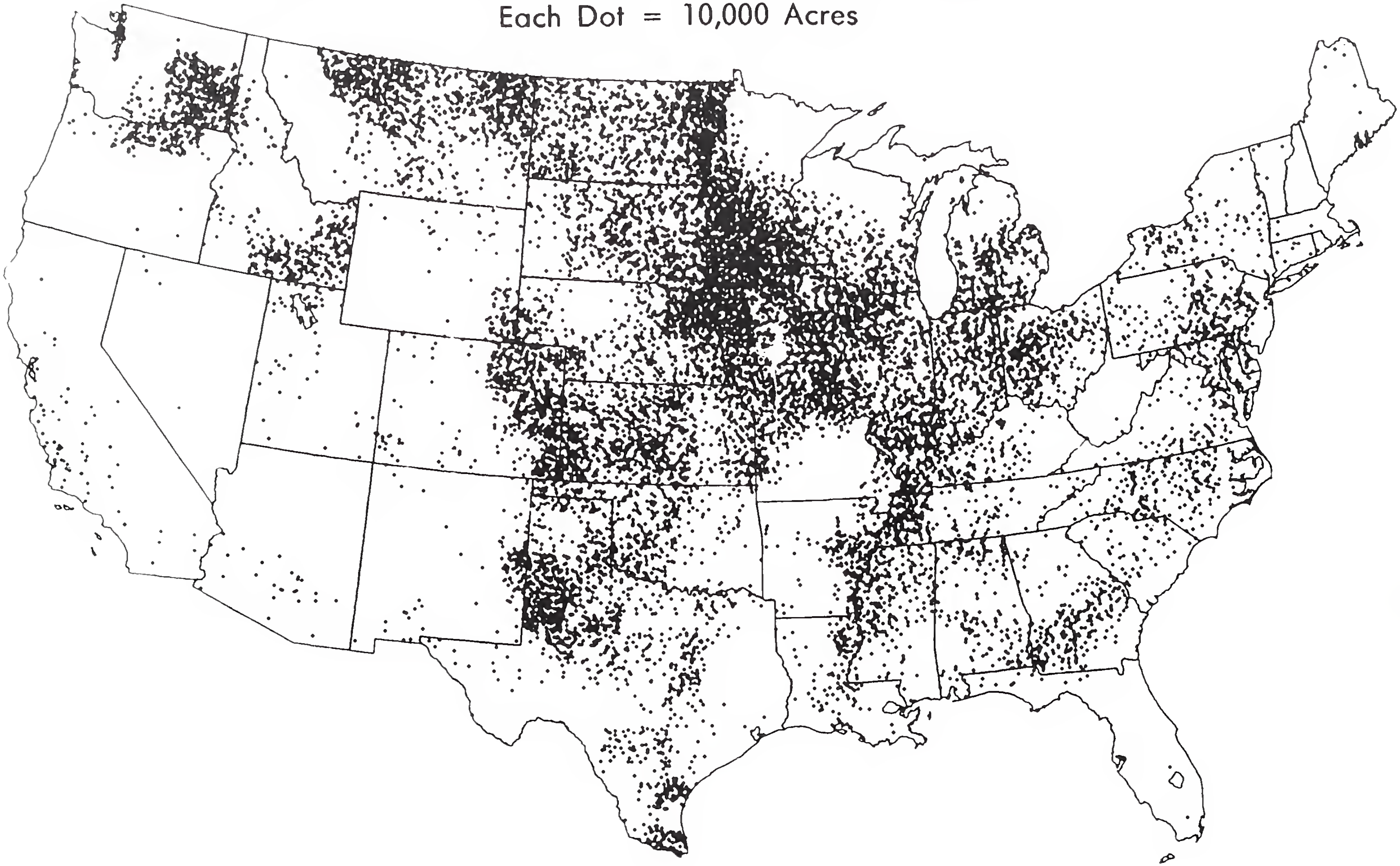
Over one-fourth, or 105 million acres, of the nation's cropland is highly erodible (Table 1). Most of the cropland, 62 percent, in the Mountain States is highly erodible. The Northeast (41 percent), Appalachian region (41 percent), and the Southern Plains (33 percent) have a disproportionate amount of highly erodible cropland. The Delta (8 percent) and Lake States (13 percent) regions have significantly lower percentages of highly erodible cropland than the national average (Figure 3.5).

Although the Northeast and Appalachian regions have above average percentages of highly erodible land, the producers in these regions have made appreciable conservation efforts that have resulted in less cropland eroding above T than the national average. The conservation effort in the Mountain region has resulted in a lower percentage of cropland eroding above T than their percentage of highly erodible land. All the remaining regions have a higher

Figure 3.3

Cultivated Cropland with Erosion Above T

Each Dot = 10,000 Acres



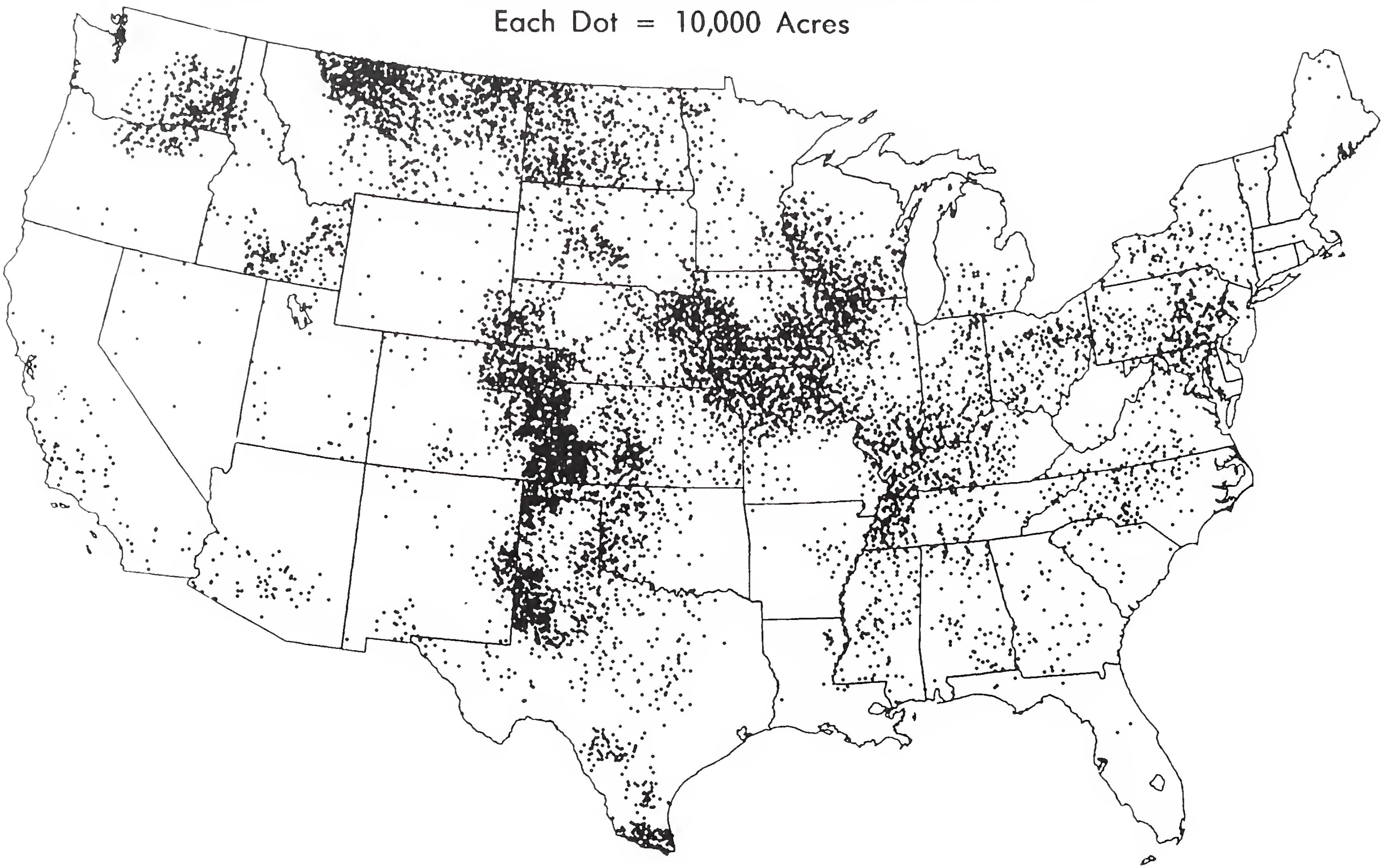
Based on 1992 National Resources Inventory

FSA EPAS

Figure 3.4

Cultivated Cropland with Erodibility Index 8 or More

Each Dot = 10,000 Acres



Based on 1992 National Resources Inventory

FSA - EPAS

Table 3.1. Erosion Problems on Cropland, 1992 1/

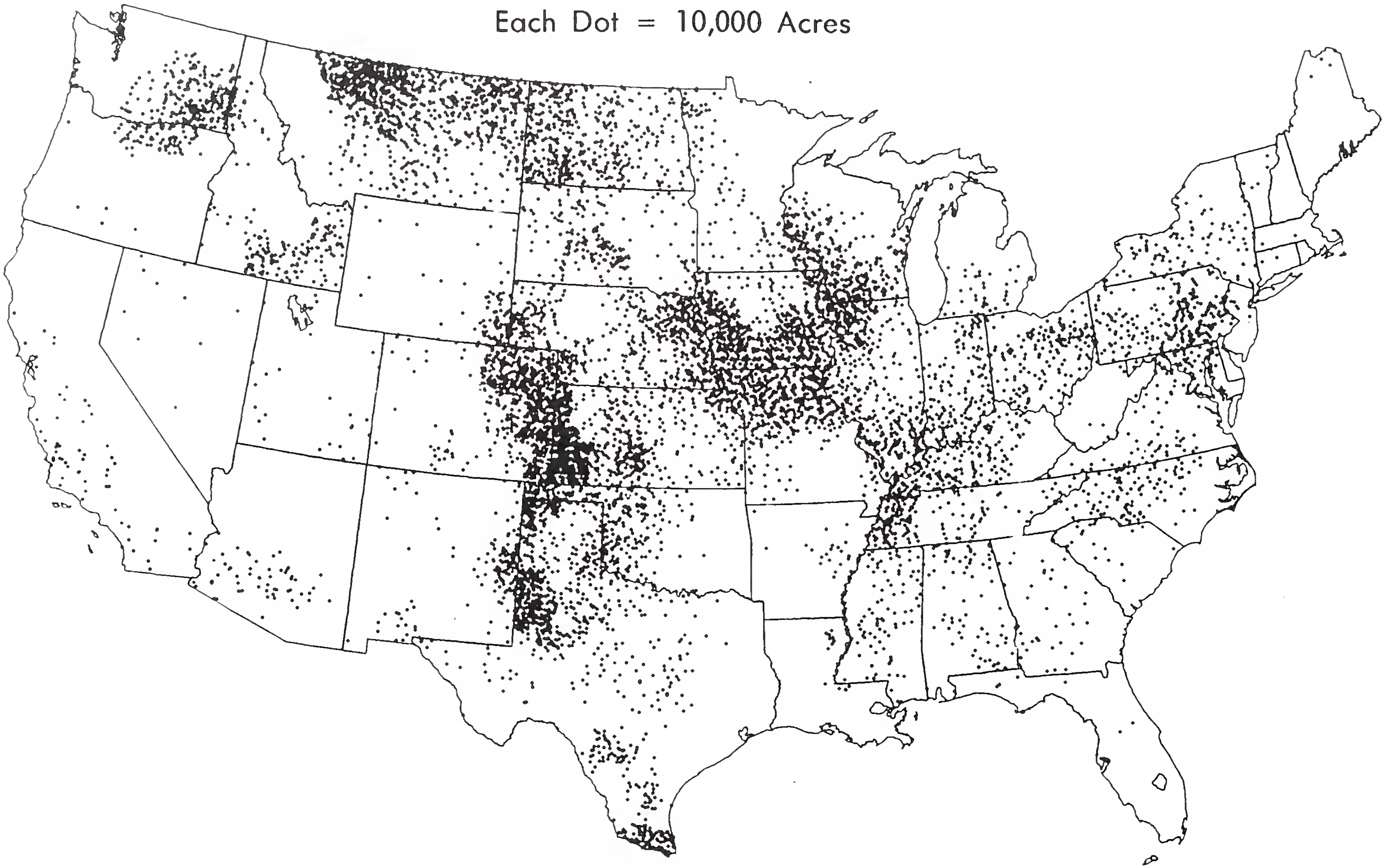
Production Region	Cropland	Unsustainable Erosion 2/	Highly Erodible 3/	Productivity Loss 4/
	1,000 acres			
Northeast	15,783	4,455	6,420	3,733
Appalachia	19,724	6,694	8,031	3,198
Southeast	14,667	4,545	2,143	1,365
Delta States	19,427	5,020	1,489	834
Corn Belt	87,876	28,606	19,968	14,763
Lake States	41,154	17,712	5,178	12,840
Northern Plains	86,984	23,696	21,543	6,146
Southern Plains	38,342	16,399	12,820	4,434
Mountain	37,513	18,350	23,444	4,257
Pacific	20,847	5,900	4,441	969
Total	382,317	131,377	105,477	52,539

1/ 1992 National Resources Inventory.
2/ Soil Loss exceeds T-value.
3/ Erodibility Index greater than or equal to 8.
4/ Yield loss greater than 2 percent in 100 years.

Figure 3.5

Cultivated Cropland with Erodibility Index of 8 or More

Each Dot = 10,000 Acres



Based on 1992 National Resources Inventory

FSA EPAS

percentage of land with erosion greater than T than they have highly erodible land. Both the Delta and Lakes States regions, which have a low percentage of highly erodible land, have much higher percentages of cropland eroding greater than the rate which can sustain crop production indefinitely.

Average erosion rates on highly eroding croplands were significantly reduced between 1982 and 1992 (Table 3.2). The percentage erosion reduction was consistently greater the higher the erosion level in all production regions. The 1982-1992 erosion reduction was the greatest in the Northern Plains, 60 percent, for croplands eroding greater than 20 tons per acre. The least percentage erosion reduction occurred in the Southeast, but erosion reduction still averaged 19 percent on cropland eroding greater than 20 tons per acre.

About 83 percent of the Nation's low erodibility cropland has controlled erosion to less than T (Table 3.3). Almost 40 percent of the nation's highly erodible cropland has erosion reduced to below T. However, over 63 million acres of highly erodible land is still in crop production and eroding greater than T.

Productivity Impacts of Soil Erosion

Erosion reduces the soil's capacity to produce crops by reducing yields and increasing expenses for fertilizer and lime. Soil erosion reduces yields by diminishing the soil's water-holding capacity, water infiltration rate, nutrient availability, and other beneficial characteristics. Erosion removes the most fertile topsoil and mixes the less fertile lower soil layers into the plant growing zone. The mixing changes the texture and chemical properties of the plow layer, especially if the lower soil layers are substantially different from the plow layer. Reduction in soil organic matter and soil structural changes caused by erosion may reduce water infiltration to the roots and reduce the amount of water the soil can hold. Yield losses caused by reduced water-holding capacity or rooting depth may be permanent.

Yield losses due to nutrient reductions can be mitigated by increased fertilizer application rates. Thinned stands due to seedling washout, coverup, or wind abrasion can directly reduce yields. Erosion can also reduce input efficiency by increasing the variability of soils within a field, which makes management more difficult.

U.S. cropland is expected to average a productivity loss of 1 percent over the next 100 years due to erosion. This is a significant reduction from the earlier estimated 100-year productivity loss of 4 to 5 percent, based on the 1982 National Resources Inventory.

Over 52 million acres of cropland in 1992 were suffering productivity loss of at least 2 percent over a 100-year period due to erosion (Table 3.1). More than 28 percent, or 14.7 million acres, of the acreage with productivity loss is in the Corn Belt (Figure 3.6). The Lake States have a disproportionately large acreage of cropland losing productivity due to erosion--24 percent of the productivity loss acreage, but only 11 percent of total cropland acreage. The Lakes States also have the highest proportion of cropland, 31 percent or 12.8 million

acres, losing productivity at rate greater than 2 percent in 100 years. The Northeast has the second

Table 3.2. Average Erosion Reduction on Cropland, 1982-1992 1/

Production Region	1982 Erosion Rate (tons/acre/year) 5 - 10	10 - 20	> 20
	Percent reduction		
Northeast	15	25	34
Appalachia	19	27	37
Southeast	11	16	19
Delta States	19	20	37
Corn Belt	30	34	42
Lake States	1	13	41
Northern Plains	36	58	60
Southern Plains	2	30	37
Mountain	-15	18	35
Pacific	-11	27	39

1/ 1992 National Resources Inventory.

Table 3.3. Excess Erosion on Highly Erodible Cropland 1/

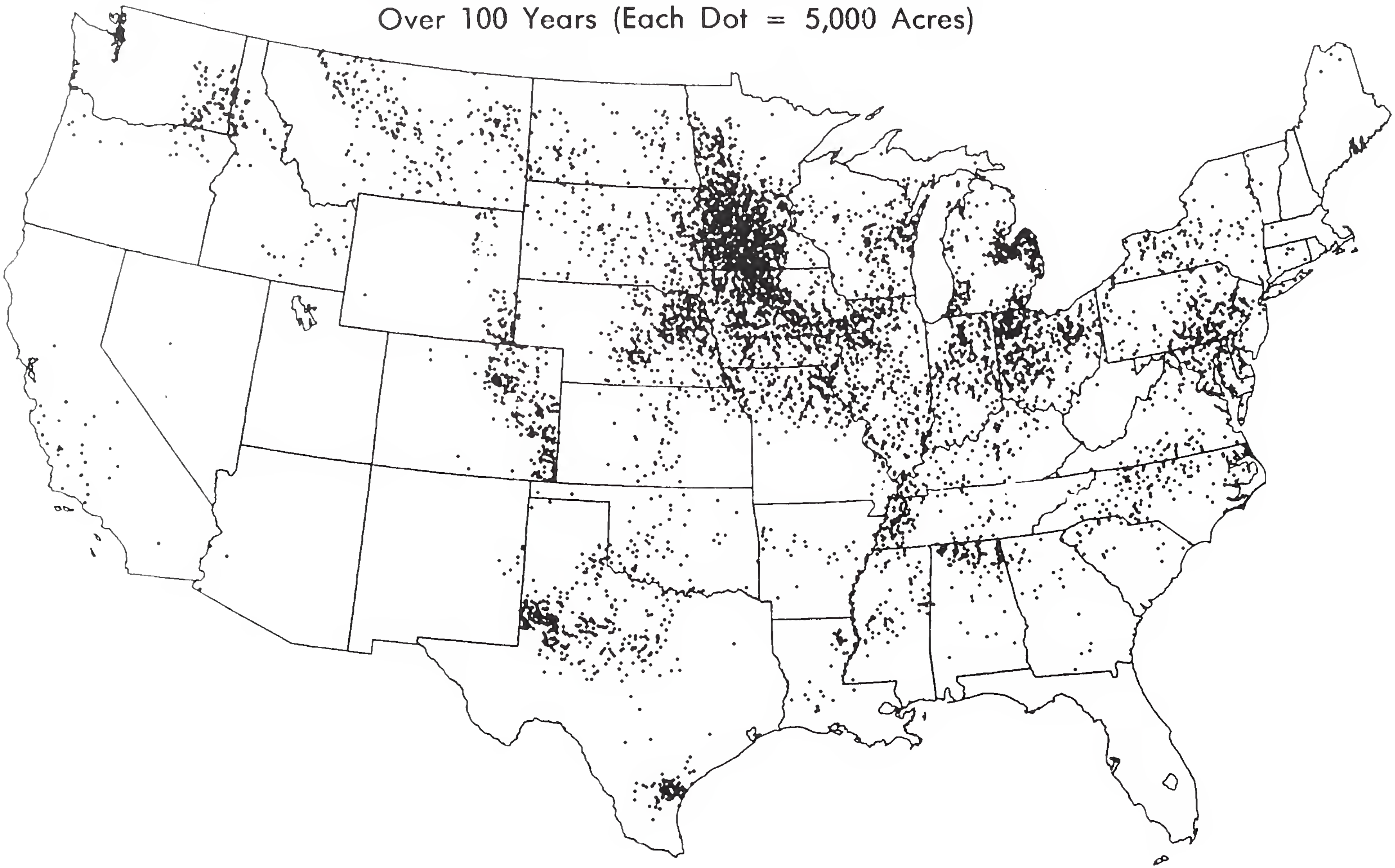
Erosion Rate	Erodiblity Low 2/	High 3/	Total
	1,000 Acres		
Sustainable 4/	208,929	42,011	250,940
Unsustainable 5/	67,911	63,466	131,377
Total	276,840	105,477	382,317

1/ 1992 National Resources Inventory.
2/ Erodibility Index is less than 8.
3/ Erodibility Index is greater than or equal to 8.
4/ Soil loss is equal or less than the T-value.
5/ Soil loss exceeds the T-value.

Figure 3.6

Cultivated Cropland with Productivity Loss > 2 Percent

Over 100 Years (Each Dot = 5,000 Acres)



FSA, EPAS

highest proportion, 23.7 percent, of its cropland losing productivity due to soil erosion. The Delta and Southeast regions have less than 10 percent of their cropland acreage losing productivity due to soil erosion because these regions do not have as large a percentage of highly erodible cropland as the other regions. The Northern Plains and Pacific regions also have less than 10 percent of their cropland losing production capacity but significant amounts of cropland in these regions are highly erodible, 25 and 21 percent respectively. Producers in these regions must be making a significant effort to control erosion.

Most of the analysis in this section is based on the 1992 National Resources Inventory. Thus the observations and conclusions are subject to error if conditions have changed since 1992. One major condition which has occurred since 1992 is the requirement that farms participating in federal programs must have a conservation farm plan implemented by 1995. (Farms had to have a plan by 1990.) Thus, much of the conservation effort, but clearly not all, mandated by the conservation compliance requirement may have been in place in 1992 and would be reflected in this analysis. The trend toward greater adoption of reduced tillage may also tend to make these conclusions an overstatement of the productivity loss problem.

Sediment

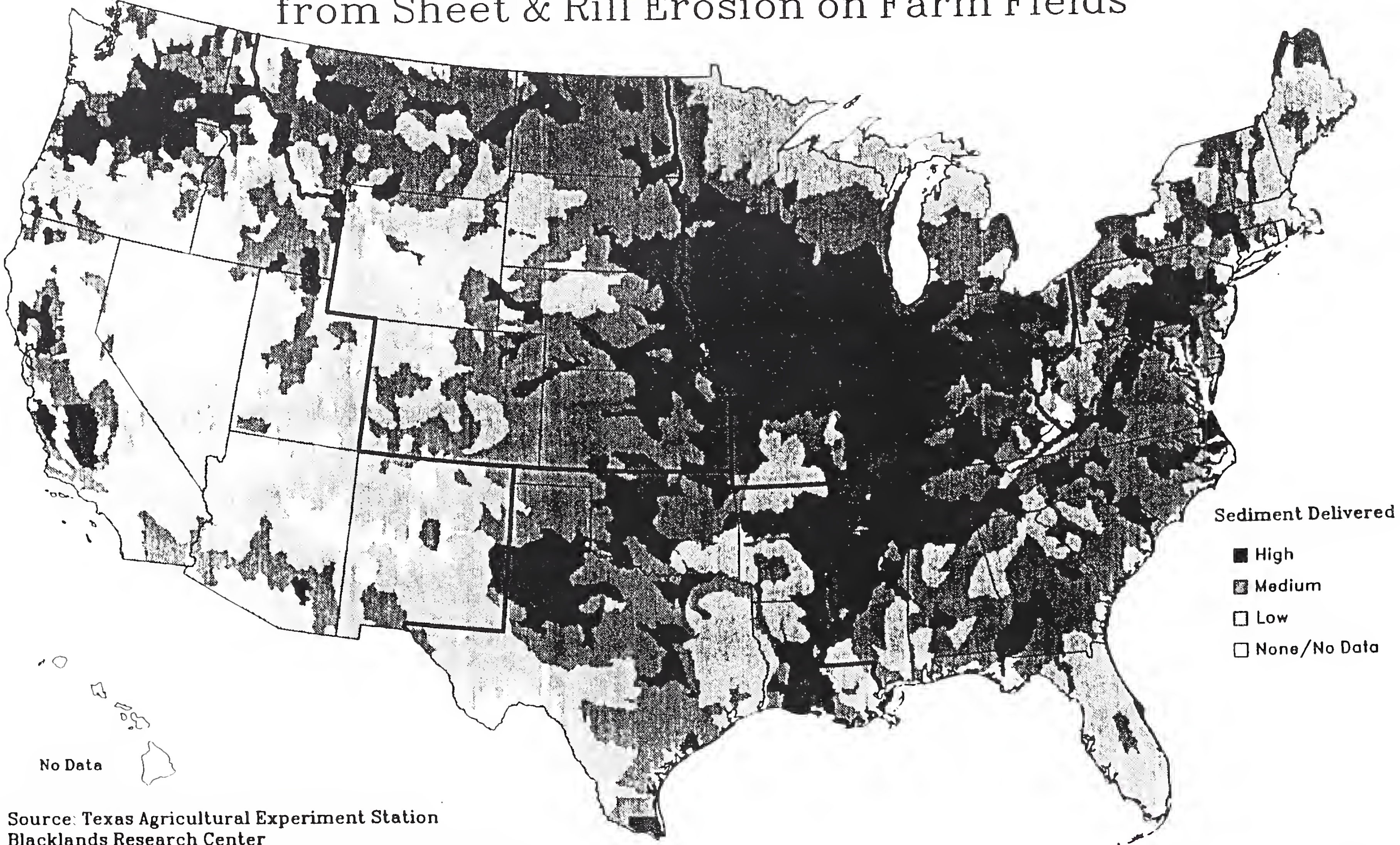
Sediment is the product of soil erosion--eroded soil is deposited in streams, rivers, lakes and on the soil surface. Total sediment delivered to rivers and streams from farm fields has been estimated at 350 million tons for 1992 (USDA 1995). Different erosion processes produce different sediment qualities. Sheet and rill erosion normally produces fine-textured sediments from the topmost soil layers. These layers contain the bulk of pesticides and fertilizers applied to the soil that adhere or become attached to topsoil particles and move with the sediment. Figure 3.7 shows the distribution of sheet and rill generated sediment from cropland across the United States. Channel erosion produces sediments from all soil layers incised by the channel. This type of erosion includes classic and ephemeral gully erosion. No reliable estimates are available to show the distribution of sediment resulting from channel erosion. Streambanks erode into previously deposited alluvial sediments that normally do not contain significant amounts of agrichemicals.

Soil erosion and resulting sedimentation is the major non-point source pollution that threatens water resources (U.S. EPA 1995). As rich productive top-soil erodes through physical and chemical forces, it becomes sediment suspended in water and deposited where it is not needed or desired. Agricultural sediments carry chemical contaminants, fill up waterbodies, and cause physical damage to farmland, wildlife, water treatment systems, and power generators.

High concentrations of suspended sediment in streams diminishs their recreational uses because pathogens and toxic substances commonly associated with suspended sediment are threats to public health. High sediment concentrations reduce water clarity and the aesthetic appeal of streams. Suspended sediment is also harmful to stream biota; it inhibits respiration and feeding, diminishes the transmission of light needed for plant photosynthesis , and promotes infections (U.S. EPA 1986). Sediment deposited on the streambed can suffocate

Figure 3.7

Sediment Delivered to Rivers and Streams from Sheet & Rill Erosion on Farm Fields



Source: Texas Agricultural Experiment Station
Blacklands Research Center
Watershed estimates are based on the USLE for erosion from agricultural lands and a delivery ratio multiplier to convert erosion to sediment loads.

Map ID: SMW.1695

benthic organisms, especially in the embryonic and larval stages. Most sediment must be removed from water intended for human use, and high sediment concentrations add significantly to the cost of water treatment. Sediment accumulations in reservoirs decrease their storage capacity and threaten their safe operation.

When erosion is significantly reduced in a watershed or river basin, a lag period occurs before the sediment concentrations in streams reflect the reductions. This result occurs because sediment entrains throughout the landscape, from the erosion source through the first stream channel to larger channels, and is temporarily stored all along this pathway. All flood plains are made of sediment deposited by rivers and streams. Typical sediment loads from the major rivers in the United States represent only 1 percent or less of the total amount of soil erosion occurring in their basins (USDA 1996b).

SURFACE WATER AND GROUNDWATER QUALITY CONDITIONS

National Water Quality Assessments

Agriculture is believed to be the biggest user as well as the biggest polluter of this Nation's fresh water. The U.S. Geological Survey (USGS 1993) estimates that irrigation and livestock uses accounted for 41.7 percent of national fresh water withdrawals in 1990 (Table 3.4). The amount of water necessary to produce food and fiber is surprisingly high. The Water Education Foundation estimates, for example, that about 11 gallons of water are needed to produce just 1 slice of white bread, and 616 gallons of water are need to produce 4 ounces of hamburger (Kreith 1991).

The U.S. Geological Survey (USGS) is the lead Federal agency for monitoring U.S. waters, collecting local water-quality information. The USGS collects information for a wide number of users ranging from Federal agencies that produce power to State and local authorities that manage in-stream flow, manage reservoirs, or allocate water between users. The USGS reports are compilations of on-going measurements from a nationwide system of stream-gaging stations, groundwater observation wells, and water-quality sampling locations of ground and surface waters. As such, they present a national profile of the impacts of agricultural practices on water quality. In 1994, USGS sampled and analyzed ground water at 6,856 stations, of which 2,756 observations were collected as part of a long-term operation. In the same year, 3,098 samples were drawn from streams and lakes, of which 771 were continuous records and 2,018 occurred under long-term studies.

Between 1983 and 1990, the USGS annually published a National Water Summary. The 1987 summary (USGS 1988) was specific to ground-water quality and the 1990/91 summary

Table 3.4. Estimated Fresh Water Use in the United States, 1990.

Category	Fresh Water Withdrawal (Million Gallons/Day)	Percentage of Total Fresh Water Withdrawals
Irrigation	137,000	40.4
Livestock	4,500	1.3
Public Supply	38,500	11.3
Domestic	3,390	1.0
Commercial	2,390	5.7
Industrial	19,300	5.7
Mining	3,310	1.0
Thermo-Electric	131,000	38.6
Total	339,000	100.0

* Source: USGS. Entries may not add to totals due to independent rounding.

(USGS 1993) was specific to stream-water quality. Other annual summaries dealt with water issues and floods. The latest summaries regarding ground- and stream-water quality provide detailed, site-specific information from on-going USGS water monitoring programs. These summaries are quoted in the following section of this report because they show direct relationships between agricultural activities and specific water quality issues on the basis of data collected by a single agency.

A second major national source is the National Water Quality Inventory (NWQI) compiled by the U.S. Environmental Protection Agency (U.S. EPA 1995). This report is required under Section 305(b) of the Clean Water Act and is a compilation of State reports. Data from the NWQI 1994 Report to Congress is used in tables to show how agriculture compares with other pollution sources regarding the impairment of various bodies of water.

The NWQI of 1994 surveyed 615,806 miles of U.S. rivers and streams out of an estimated national total of 3.5 million miles. Of the surveyed river and stream miles, 64 percent are considered good, but 36 percent, or 224,236 miles, are considered impaired. The leading pollutants (followed by the percent of impaired miles wherein the pollutants were found) are bacteria (34 percent); siltation (34 percent); nutrients (23 percent); oxygen-depleting substances (18 percent); metals (17 percent); habitat alterations (16 percent); and suspended solids (14 percent). The leading source of these pollutants, nationally, is agriculture. Agriculture was determined to be a pollutant source in 60 percent of the impaired miles.

State-Level Indicators of Agricultural Impacts on Water-Quality

Following are excerpts from the USGS National Water Summaries dated 1986 and 1990/91 showing direct links between various agricultural activities and contaminants of ground and surface waters. These comments are included here to show the widespread nature of agriculture/water quality linkages as documented by a single, national level agency. Additional documentation of these linkages has been developed by many other state and local agencies, but the USGS findings are compelling due to that agency's longstanding and continuing responsibility to water-quality monitoring.

Some State-level assessments contained in both the USGS reports and the NWQI indicate the difficulty of determining exact sources of pollution when there are several co-located likely sources. Other comments indicate that the withdrawal of land from agricultural uses and the implementation of various conservation practices have improved trends in water quality and that concentrations of agricultural activities do not necessarily result in surface water or groundwater degradation. These State-level comments are included to highlight local issues that would otherwise be obscured by National-level statistics.

Arkansas: Groundwater withdrawals for irrigation, industrial, and public-supply use have contributed to the deterioration of groundwater quality in Arkansas. The widespread use of insecticides and herbicides essential to crop production has the potential to affect the groundwater. Heightened nitrate levels at one measurement point on the Tennessee River are possibly due to agricultural activity in the river basin and wastewater discharge from numerous cities. Heightened nitrate levels at one site on the Kings River was downstream from a sewage treatment plant, and chicken, pig, and cattle operations--typical point and non-point sources of nitrogen, phosphorus, and other contaminants. Total nitrite plus nitrate concentrations had no trend at 8 of the 10 monitoring stations from which data were suitable for trend analysis.

California: Widespread use of pesticides in the Central Valley and parts of Imperial, Riverside, and San Bernardino Counties has contaminated hundreds of wells. Of 8190 private and public wells sampled from 1979 through 1984, 2522 had Dibromo-chloropropane contamination. More than 50 other pesticides had been detected in samples from 255 wells through 1984. In the central part of the western San Joaquin Valley, selenium concentrations in shallow ground water and subsurface agricultural drainage water commonly exceeded 100 ug/L, and in places exceeded 1,000 ug/L. Upstream from site 11 on the San Joaquin River, increased irrigation return flow and runoff from dairies and feedlots were the primary reasons for the upward trend of dissolved nitrites and nitrates.

Colorado: In the High Plains, ground water along the valleys of the Arikaree and South Fork Republican Rivers has a larger dissolved solids concentration than groundwater in adjacent areas where depths to water are greater and irrigation has been practiced for a shorter time. Irrigated agriculture along Black Squirrel Creek may have contributed to increased concentrations of dissolved nitrate in the alluvial aquifer. Concentrations of fecal coliform

bacteria had no significant trend at any of the six stations tested during the period 1980-89. A site on the Arkansas River that monitors an area of extensive agricultural activity showed no trend in sulfate concentrations.

Connecticut: During the Fall of 1983, contamination of groundwater by a soil fumigant used for tobacco was detected and found to affect at least 50 square miles in north-central Connecticut. Through August 1986, water samples from 268 private and 54 public wells have had ethylene dibromide (EDB) concentrations that equaled or exceeded the drinking-water standard established for Connecticut, making this the most significant ground-water problem in the State. Nitrite plus nitrate concentration had no trend during 1980-89 at the 4 monitoring stations from which the data were useable for trend analysis. The downward concentrations of phosphorus in eight streams can be attributed to decreasing agricultural land use and improved agricultural practices that include changes in fertilizer application, animal waste control, and erosion and sedimentation control.

Delaware: Nitrate contamination was extensively documented. The largest nitrate concentrations were down gradient from chicken houses. Chloride, calcium, magnesium concentrations increased above background levels. Evidence was found that irrigation promotes leaching of nutrients and chemicals into the groundwater. Trends indicate nutrient contamination will increase. The decrease in nitrate concentration in the St. Jones River might have resulted from reduction of nonpoint nitrogen contributions as land in the basin was converted from agricultural to nonagricultural uses.

Florida: Pesticide contamination of groundwater has become a major environmental issue. EDB was found in groundwater in 22 of 66 tested counties. (Aldicarb has been detected in groundwater trace concentrations in 3 of 91 major public supplies.) Pesticides are common contaminants near landfills. Most of the adverse stream conditions were ascribed to nonpoint runoff from agricultural areas and from urban areas that are increasing in size throughout the State. Water in the Miami Canal is adversely affected by agricultural and urban runoff and by sewage effluent. In some reaches of the Chipola River, agricultural runoff causes elevated nitrogen concentrations and sedimentation.

Georgia: EDB may have moved into aquifer system--6 of 19 wells tested positive. Upward trends in phosphorus at several river points were the result of a combination of urban point-source and agricultural nonpoint-source effects.

Hawaii: Intensive pumping of the basal freshwater for irrigation has caused intrusion of saline water. Pesticides and other organic compounds have reached the basal aquifers. Ten wells were closed to eliminate 1, 2-dibromo-3-chloropropane (DBCP) and ethylene dibromide (EDB) from drinking water supplies. The upward trend in fecal coliform bacteria contamination in the Waimea River was possibly caused by either increasing numbers of cattle in the basin or increasing runoff from grazing land.

<u>Idaho</u>: The economy is dominated by agriculture, and groundwater is the principal source of more than 90 percent of public water. Many drinking water supplies are pumped from relatively shallow aquifers. Irrigation practices and wastewater applications from agriculture-related activities are major sources of recharge to many aquifers and are direct/indirect sources of nitrate, iron, organic compounds, and bacteria contaminants. Water uses, such as agriculture and hydroelectric power generation could conflict with growing demand for water of suitable quality for domestic consumption and recreation. Low concentrations of fecal coliform, nitrates and nitrites, and phosphates indicate that livestock, and crop production, and urban activities in the Couer d'Alene and Clearwater Basins have not affected water quality substantially.

<u>Illinois</u>: In North-Central Illinois, increased nitrate concentrations are associated with septic-tank wastewaters and areas of agricultural fertilizer usage. Agriculture has the potential for affecting water quality over wide geographic areas. Shallow aquifers are susceptible to changes caused by irrigation and to animal waste contamination. An estimated 97 percent of rural-domestic water systems are supplied from shallow aquifers. Decreases in urban and agricultural runoff probably caused the decreasing phosphorus concentrations in the Sangamon, Illinois, and Kaskaskia Rivers.

<u>Indiana</u>: Thirty-one percent of fishkills reported during 1986-87 were attributed to contamination caused by agricultural activities.

<u>Iowa</u>: Agricultural pesticides have been detected in water from both public and private wells. Pesticides are often detected in water that also contains substantial concentrations of nitrates. Recent investigations have found detectable quantities of atrazine throughout the year in groundwater. Nitrate concentrations are largest during the early part of the growing season. Sediments, nutrients, and pesticides primarily attributed to agricultural non-point sources were identified as affecting 99 percent of the stream miles that did not fully support designated uses. Pesticides were identified as having minor to moderate effects on 91 percent of the stream miles assessed during 1988-89. The pesticides most frequently detected in Iowa surface water are alachlor, atrazine, cyanazine, metolachlor, and metribuzin.

<u>Kansas</u>: Herbicides were detected in water from the High Plains aquifer in north-central Sedgwick County. There remains potential for additional contamination of ground water from agricultural practices. Wastes found in sites investigated under the Resource Conservation and Recovery Act include agricultural chemicals. Runoff from agricultural land is a major cause of stream water quality degradation. In more than half of the stream miles assessed in 1988-89, water quality problems were the result of organic enrichment from cropland runoff. Pesticide residues in surface water are another major consequence of agricultural activity in the State.

<u>Kentucky</u>: Aquifers in karst terrain are extremely vulnerable to contamination from storm water runoff from agricultural areas. Known or potential sources of groundwater degradation include agricultural activities. Isolated contamination incidents have been associated with

pesticides and nitrates. The main sources of fecal coliform bacteria contamination are municipal discharges and agricultural runoff.

Louisiana: Concern is increasing about contamination of ground water by surface waste disposal and use of agricultural chemicals. State-wide water quality concerns include high iron concentrations and pesticide residues in water and trace insecticide residues in stream and lake bottom materials.

Maine: Water from 30 wells is restricted due to pesticide contamination. One-quarter of sample wells in a cattle farm test area had nitrate concentrations that exceeded the drinking-water standard. Other water quality problems result from acid rain, construction, crop production, animal grazing, timber harvesting, and waste disposal. The absence of upward trends in suspended sediment might be due to a decrease in agricultural activities in many areas of the State.

Maryland: Excessive use of nitrogen is suspected to be a factor in increased nitrate levels in groundwater. Seven percent of 1521 tested wells exceeded the national drinking-water standard. Nitrate concentrations tended to be larger at sites with urban and agricultural land uses and moderately well-drained soils. Common causes for stream use impairments were excessive concentrations of nutrients, sediment, and bacteria from agricultural and urban runoff, mining and municipal discharges, land disposal, and industrial discharges. Other important water-quality concerns in the State are stream acidification in western Maryland due to mine drainage and acid precipitation; pesticides such as chlordane in agricultural runoff; and the effects of organic and trace-metal toxic substances from industrial sources.

Massachusetts: Agricultural pesticides have been detected in groundwater in the Connecticut River valley in central Massachusetts. Public wells have been closed in several counties due to contamination by ethylene dibromide (tobacco soil fumigant). Water from 52 wells in the Connecticut River valley has been identified as exceeding standards for a number of pesticides. State tests of 556 wells showed 11 percent exceeded pesticide drinking water standards. Water quality in the lower Connecticut River basin south of Springfield has been degraded by combined-sewer overflows and overland runoff from agricultural and urban areas.

Michigan: Agriculture and food-related activities blamed at 3 percent of 739 contaminated sites. Nitrate concentrations that exceed drinking-water standards are found around the State. Nitrate concentrations of 18 mg/l found in areas of intensely fertilized cherry orchards. The increasing nitrites plus nitrate concentrations in the Raisin River upstream from Monroe might have been the result of increasing nitrogen fertilizer use in the basin. (The increase corresponds to increased nitrogen use.) Downward trends in phosphate contamination in primarily agricultural basins might be the result of a decreased use of phosphorus fertilizers between 1980 and 1985.

Minnesota: Concentrations of nitrates and nitrites in the karst areas commonly exceed the primary drinking-water standard. Water in the Prairie du Chien-Jordan aquifer has been contaminated as a result of agricultural activity . Runoff from agricultural areas along the Minnesota River is of particular concern because of contamination from sediment and agricultural chemicals.

Mississippi: Some of the more persistent pesticides are present in the water and bottom sediments of the Yazoo River. Significant quantities of dichloro--diphenyl-trichloro-ethane (DDT), dichloro-diphenyl-dichloro ethane (DDD), dichloro-diphenyl-dichloro-ethylene (DDE), and toxaphene are found in surface water and in fish tissue. In 1983, about 8000 tons of pesticides were applied to 2 million acres of crops in the Mississippi Delta. Nonpoint agricultural runoff is a major cause of degraded water quality. Most of the streams that do not fully support designated uses have been degraded by nutrients and siltation, whereas the remainder have been contaminated by pesticides, and other agricultural priority organic chemicals, etc.

Missouri: In 1986, no agency or State program monitored the sale or use or non-restricted pesticides. In 1980, numerous pesticides were detected in water at concentrations above levels safe for aquatic life. Aldrin, chlordane, DDT and DDE are found in sediments from major rivers and ditches draining southeastern Missouri. Two issues of statewide concern are contamination of surface waters by agricultural chemicals and contamination of fish by chlordane. Herbicides have been detected in streams in northern Missouri.

Montana: Agricultural practices of the central and eastern plains have resulted in the widespread and rapidly expanding problem of saline seeps. No widespread contamination of groundwater by fertilizers or pesticides is known to exist, but some localized problems have occurred. Regulatory efforts to control cattle feedlots and upgrading of community waste treatment probably account for the downward trend in coliform bacteria.

Nebraska: Large increases in the use of fertilizers and pesticides have accompanied irrigation development and have provided the potential for widespread nitrate and pesticide contamination of shallow groundwater. Pesticides in groundwater are being detected. Nitrate concentrations exceeding 10 mg/l are detected in an area of 340 square miles. Other tests indicate increases in nitrate concentrations over time. Non-point source contamination was responsible for 71 percent of stream water quality degradation. The principal nonpoint contamination source in Nebraska is agricultural runoff, which increases levels of fecal coliform bacteria, suspended solids, and some pesticides.

Nevada: Areas of potential contamination are associated with irrigation, feedlots, and dairy farms. Shallow groundwater from drains under irrigated fields contain large arsenic concentrations derived from the soil as the irrigation water percolated to the shallow water table. Water quality in the Colorado River has been affected by agricultural runoff, runoff from naturally saline springs and soils, and discharge from municipal wastewater treatment plants.

New Jersey: Several dozen rural domestic wells have been closed because of increased nitrate levels resulting from agricultural practices or septic systems. Agriculture is identified as one cause of severe groundwater degradation in some areas. Agricultural runoff is included among the major sources of water quality degradation in the State.

New Mexico: Concentrated dairy farms are one cause of aquifer water quality degradation. Depletion due to irrigation in the eastern and southern parts of the State may reduce agricultural activities there. Many different pesticides have potential to percolate into underlying aquifers. Pesticides cause contamination intermittently in the Rio Grande River downstream from Cochiti Reservoir.

New York: Many of the State's aquifers are exposed to actual or potential sources of contaminants. Some are nonpoint, such as agriculture. Pesticide contamination of ground water is a serious problem. The greatest cause is agricultural production, especially potato farming. Wells have been closed. By April 1984, aldicarb had been detected in about 2,000 private wells in concentrations exceeding the State drinking-water standard. In the Cattaraugus Creek, the high nitrite plus nitrate concentrations indicate local water quality degradation by agricultural runoff and municipal waste-water discharges.

North Carolina: Pesticides were detected in 202 private wells and 1 public well. Many contaminated wells were found in areas where the pesticides were applied. Contamination occurs throughout the State. Many contaminations are due to termite treatments. In general, the major causes of impaired stream use were nonpoint sources such as agricultural runoff, urban runoff, and construction.

North Dakota: Nitrate contamination of ground water has been detected at many feedlots, corrals, and farmsteads. Excessive nitrate concentrations were found in 22 wells south of Oakes. The major sources of contaminants were nonpoint, primarily runoff from nonirrigated cropland, pastureland, and feedlots.

Ohio: Pesticide applications around homes are one of several leading sources of contamination of well water. Runoff of agricultural chemicals is an important water quality issue in the Scioto River basin. For example, Columbus, which uses the Scioto River for water supply, has issued drinking water alerts during spring runoff because of nitrate concentrations in excess of 10 mg/l at the water intake.

Oklahoma: The State began to look for pesticides in groundwater in 1986. Fertilizers and pesticides from agricultural areas in the Salt Fork-Arkansas River basin contribute nitrogen and phosphorus and organic compounds to the reservoir. Extensive agricultural activities in the basin probably contribute to large concentrations of bacteria, nitrites and nitrates, phosphates, and suspended sediments.

Oregon: Examples of agricultural related water quality problems include large nitrate concentrations in areas of the Willamette Valley west of the Cascades and the Ontario area of

Malheur County. Pesticide contamination was found in the Willamette Valley, and dactyl and ptyalin in the Ontario area. Uses of the John Day River are sometimes not fully supported due to degraded water quality caused by agricultural runoff.

Pennsylvania: Atrazine, simazine, alachlor, and metolachlor were found almost exclusively in the groundwater of the agricultural carbonate areas. Excessive application of manure and chemicals has led to the deterioration of groundwater quality in many intensively farmed areas.

Rhode Island: Since 1984, aldicarb has been found in 169 of 980 drinking water wells. One of the wells was a public well serving 20,000 people. Leaching of inorganic nitrogen fertilizers in Washington County increased nitrate concentrations substantially above background levels.

South Carolina: Contamination of the water table aquifer in an area of about 5 square miles north of Summer has been attributed to agricultural sources. Nitrate concentrations as high as 12 mg/l were traced to a combination of fertilizer application, septic tank, and animal feedlot sources.

South Dakota: Inorganic and organic nutrients resulting from feedlots, septic tanks, and improper handling and storage of fertilizers have contaminated several community and private water wells. Pesticide contaminations have been documented. Nitrate plus nitrite concentrations in excess of 10 mg/l because nitrogen are common in water from wells near feedlots.

Tennessee: In Hardeman County, 13 private drinking water wells contaminated by pesticides were abandoned. Agricultural activities are included among the major sources of degraded water quality in the State. However, many streams in western Tennessee carry large sediment loads because soils in the agricultural areas are easily eroded.

Texas: Arsenic from cotton gin waste has contaminated a limited part of the High Plains (Ogallala) aquifer. Effects of widespread pesticide and fertilizer use throughout much of the State have not been determined. Non-point contamination sources such as agriculture, oil and gas exploration and production, urban runoff, are the origins of most contamination in streams.

Utah: Use of ground water for irrigation has contributed to the deterioration of groundwater quality in the Sevier Desert, Pahvant Valley, and the Beryl-Enterprise areas. Recirculation of groundwater for irrigation has intensified the accumulation of salts in the Beryl-Enterprise area. Most commonly, the rivers that did not support designated uses contained excessive concentrations of dissolved solids and toxic metals. Geologic or natural nonpoint sources of pollution caused most of the contamination, followed by agricultural sources.

Vermont: Application of chemical fertilizers has increased nitrate concentration in aquifers in Orleans and Windsor Counties. In Caledonia County, the groundwater was contaminated when manure was dumped directly into a gravel pit dug into a stratified drift aquifer. Another shallow aquifer was contaminated by a nearby open silage pit. Overall, the major causes of nonpoint source pollution of stream water are agricultural runoff, construction-site erosion, flow regulation, and streambank modification or destabilization. Water quality in the Black River is affected by agricultural runoff of fertilizer and animal wastes and erosion.

Virginia: Agricultural practices are listed as among the most widespread sources of contamination of ground water. Nitrate contamination, derived from feedlots, fertilization practices, or animal waste disposal, continue to threaten the quality of the shallow ground water system, particularly in the Coastal Plain and Valley and Ridge regions. Land use in the Chickahominy Basin upstream has gradually changed from agricultural to residential with Richmond area. This change could have led to decreased nutrient input to expansion of the streams.

Washington: Large nitrate concentrations in several domestic and public supply wells in rural areas throughout the Columbia plateau have been associated with long-term application of fertilizers. Several wells in berry-producing areas tap aquifers contaminated beyond safe levels with soil fumigants. Pesticides, bacteria, and suspended solids in the Okanogan River were identified by the State as degrading the water quality and occasionally limiting the use of the water for designated purposes. Agricultural nonpoint sources of these contaminants are partly responsible for the water quality degradation.

West Virginia: Nitrate concentrations in excess of 10 mg/l have been detected near feedlots and in agricultural areas where fertilizers have been applied. Picloram and chlordane are the pesticides most commonly detected in ground water. Of 155 water supplies in Preston County, 68 percent exceeded the primary drinking water standard for coliform bacteria.

Wisconsin: Of 793 wells in Columbia County, 38 percent had nitrate levels exceeding drinking water standards. Pesticides have been detected in two State sampling programs. The most commonly detected pesticides found by one study were atrazine, alachlor, metolachlor, and cyanazine. Agriculture is the most common source of water quality problems in streams not fully supporting beneficial uses.

Wyoming: Nitrate contamination nitrate is fairly common in agricultural areas. Large nitrate concentrations have been detected in ground water samples from wells in agricultural areas in Laramie, Goshen, Fremont, Washakie, Bighorn, and Park Counties. Irrigation drainage is a major source of the large selenium concentration of Poison Spider Creek. Agricultural activities and sewage effluent affect water quality conditions in the Powder River.

National-Level Measures of Agricultural Impacts on Water Quality

The 1994 NWQI identified the leading sources of pollution impairing surveyed rivers and streams. Of an estimated 3,548,738 total river miles in the Nation, 615,806 river miles were surveyed. Most of the surveyed rivers and streams flow all year and represent about 48 percent of the 1.3 million miles of rivers and streams that flow all year. Of those surveyed miles, 224,236 miles, or 36.4 percent, were found to be impaired, with agriculture identified as a major source of impairment (See table 3.5) .

Table 3.5. Leading Sources of Pollution Impairing Surveyed Rivers and Streams.

Level of Pollution	**Major**	**Moderate/ Minimum**	**Not Specified**	**Total**
	Miles of Surveyed Streams and Rivers			
Agriculture	55,443	57,067	22,047	134,557
Natural	13,799	18,164	10,312	42,275
Municipal Point Source	11,244	21,805	4,394	37,443
Hydro/Habitat Modification	8,448	19,773	8,859	37,080
Urban Runoff/Storm Sewers	9,746	12,633	4,483	26,862
Resource Extraction	6,702	10,404	6,953	24,059
Removal of Riparian Vegetation	12,516	6,338	2,852	21,706
Forestry	2,674	6,426	11,215	20,315
Industrial Point Sources	4,386	8,571	3,391	16,348
Other 1/	25,618	56,840	16,405	98,863
	Percent of Impaired River Miles			
Agriculture	25	25	10	60
Natural	6	8	5	19
Municipal Point Source	5	10	2	17
Hydro/Habitat Modification	4	9	4	17
Urban Runoff/Storm Sewers	4	6	2	12
Resource Extraction	4	5	3	11
Removal of Riparian Vegetation	6	3	4	17
Forestry	1	3	5	9
Industrial Point Sources	2	4	2	7
Other 1/	<15	<25	<13	45

1/ Includes the combined miles from non-specified sources, streambank destabilization, channelization, petroleum activities, construction, land disposal, recreational activities, flow regulation, onsite wastewater systems, highway maintenance and runoff, and land development.

The 1994 NWQI also identifies the sources of agricultural pollution for the 134,557 river and stream miles impaired by agricultural activities. These sources are shown in the following table (Table 3.6) which indicates the miles impaired by pollution source, and the percent of total impaired miles by source of pollution.

Table 3.6. Agricultural Sources of Pollution in Surveyed Rivers and Streams, by Miles of Rivers and Streams, and Percent of Total River Miles Impaired.

Level of Pollution	Major	Moderate/ Minimum	Not Specified	Total
	Miles of Surveyed Rivers and Streams			
Non-irrigated Crop Production	16,965	14,645	514	32,124
Irrigated Crop Production	14,975	11,090	3,219	29,284
Rangeland	3,067	12,400	11,769	27,236
Feedlots	14,156	6,902	214	21,272
Pastureland	1,400	9,191	3,769	14,360
Animal Holding Areas	939	2,483	751	4,173
	Percent of Total River Miles Impaired by Agriculture			
Non-irrigated Crop Production	13	11	<1	24
Irrigated Crop Production	11	8	2	22
Rangeland	2	8	9	20
Feedlots	1	5	<1	16
Pastureland	1	7	3	11
Animal Holding Areas	1	2	1	3

Note: river miles impacted by individual agricultural activities do not add to the total river miles impaired by agriculture in general for the following reasons: (1) less than half of the 49 States, Tribes and Territories that reported impacts from agriculture, in general, identified specific agricultural activities contributing to water quality impacts; (2) the 21 States that did provide more detailed information could not identify specific agricultural activities causing impacts in all waterbodies impacted by agriculture; (3) more than one activity may impact a single river or stream and EPA tabulates the miles impacted by each activity separately

Agriculture is also identified as a leading source of lake, reservoir, and pond pollution. In the following table the total acres of these waterbodies polluted by agricultural activities are compared with acreages polluted by other sources. Of a total 17, 134,153 acres surveyed, 6,682,200 were found to be impaired. Agriculture was found to be a polluter of 50 percent of those impaired acres.

Table 3.7. Leading Sources of Pollution Impairment at Surveyed Lakes, Reservoirs, and Ponds.

Level of Pollution	Major	Moderate/ Minimum	Not Specified	Total
	Acres Impaired			
Agriculture	681,875	2,311,210	356,500	3,349,585
Municipal Point Source	240,086	983,378	42,670	1,266,134
Urban Runoff/Storm Sewers	297,201	820,103	82,904	1,200,208
Unspecified	689,687	253,321	45,706	988,714
Natural	138,039	469,754	357,334	965,127
Hydro/Habitat Modification	307,218	429,453	95,481	832,152
Industrial Point Sources	295,740	460,900	2,471	759,111
Land Disposal	137,955	574,935	0	712,890
Construction	159,277	459,618	6,006	624,901
Flow Regulation	54,160	354,102	44,938	453,200
Highway Maintenance/Runoff	42,044	383,371	0	425,415
Contaminated Sediments	114,269	265,629	1,285	381,183
Atmospheric Deposition	21,792	150,853	196,703	369,348
Septic Systems	78,464	244,109	13,129	335,702
Forestry	9,642	294,488	3,236	307,366
Resource Extraction	118,210	109,242	9,547	236,999
Shoreline Modification	8,779	195,021	26,919	230,719
Land Development	46,376	146,490	10,691	203,557
Recreational Activities	25,575	161,051	3,202	189,828
Spills	29,547	103,057	0	132,604

The 1994 NWQI also presents data regarding the pollution of estuaries, and although agriculture is not identified as the leading source, it ranks among the major sources. The NWQI surveyed 26,847.3 square miles of estuaries. Of that total surveyed, 9,699.82 square miles (36.1 percent) were considered as having an impaired use. Urban runoff/storm sewers and municipal point sources were identified as impairing more total estuary acreage than

agriculture. A comparison of the square miles impaired by these leading sources is shown in the following table.

Table 3.8. Leading Sources of Pollution Impairing Surveyed Estuaries.

Level of Pollution	Major	Moderate/ Minor	Not Specified	Total
	Square Miles Impaired			
Urban Runoff/Storm Sewers	502.41	3,845.35	160.16	4,507.92
Municipal Point Sources	768.58	2,935.49	122.71	3,826.78
Agriculture	562.70	2,563.52	195.15	3,321.37
Natural	396.53	2,304.66	247.70	2,948.89
Industrial Point Sources	435.27	2,153.80	20.21	2,609.28
Petroleum Activities	522.90	785.80	0.0	1,308.70
Construction	143.55	1,109.86	0.0	1,253.41
Land Disposal	1.97	1,135.22	80.20	1,217.39
Upstream Sources	0.0	1,079.00	0.0	1,079.00
Unspecified	30.31	642.27	318.30	990.88
Spills	522.90	228.12	0.0	751.02
Combined Sewer Overflows (CSOs)	168.77	357.99	0.0	526.76
Resource Extraction	75.88	438.13	0.0	514.01
Contaminated Sediments	116.78	278.11	0.0	394.89
Marinas	5.36	195.71	113.23	314.30
Onsite Wastewater Systems	11.05	193.67	66.76	271.48
Wastewater Lagoon	0.0	252.0	10.58	262.58
Atmospheric Deposition	0.0	235.62	0.0	235.62
Silviculture	0.08	235.0	0.0	235.08
Recreational Activities	2.26	164.42	13.8	180.48

The NWQI also examined ocean shoreline waters for impairment. Although agricultural practices are commonly thought to be removed from ocean sites, it was found that agriculture ranked as the sixth highest source of ocean water impairments.

Table 3.9. Leading Sources of Pollution Impairing Surveyed Ocean Shoreline Waters (Shore Miles).

Level of Pollution	Major	Moderate/ Minimum	Not Specified	Total
	Shore Miles			
Urban Runoff/Storm Sewers	38	141	0	179
Industrial Point Sources	19	107	0	126
Natural	19	75	0	94
Land Disposal	15	77	0	92
Onsite Wastewater Systems	0	87	0	87
Agriculture	10	64	0	74
Other Nonpoint Sources	35	37	0	72
Combined Sewer Overflows (CSOs)	3	40	0	43
Recreational Activities	0	40	0	40
Municipal Point Sources	8	20	0	28
Atmospheric Deposition	0	12	0	12
Spills	0	11	0	11
Ground Water Loading	0	11	0	11
Land Development	0	9	0	9

In the 1994 NWQI, agriculture was identified more frequently (8 times) than any other source as degrading the integrity of wetlands. Urban runoff was the second most frequently reported source (6 times). Out of 61 reporting States, Tribal Nations, and Territories, agriculture was identified as the leading source of wetland degradation in California, Iowa, Kansas, Maine, Maryland, Puerto Rico, and by the Hoopa Tribe.

The causes of 737 reported fish kills due to toxins and other pollutants were identified by States in the 1994 NWQI. Ninety nine fish kills were attributed to pesticides, with the following States having the greatest number of events: Kansas (21), Louisiana (18), Mississippi (6), South Carolina (6), Oklahoma (5), Alabama (5), and Georgia and Virginia (4). Twenty-two fish kills were attributed to herbicides, with the largest number occurring in Florida and South Carolina, each State having 5 events. Pesticides and herbicides of unspecified sources combined accounted for 30 percent of the 404 reported fish kills due to toxins. The leading source of such kills was the category combining unspecified or less common toxic chemicals, such as disinfectants, road tar, deicing chemicals, and

aromatic hydrocarbons. This category was cited as causing 126 (31 percent) of the 404 reported kills.

Agriculture was identified as the leading source of fish kills in all States among 22 categories of activities. The sources of fish kills, as reported in the 1994 NWQI, and the number of fish kills attributed to each source were: agriculture, 139 kills or 24.8 percent; sewage treatment plants, 86 kills or 15.3 percent; industry, 76 kills or 13.5 percent; spills, 69 kills or 12.3 percent. The remaining reported kills were attributed to 18 miscellaneous sources. Of the 139 fish kills attributed to agriculture, the States having the most reported incidents were Louisiana (18), Pennslyvania (17), Florida (16), Kansas (14), Nebraska (13), and Virginia (8).

Table 3.10. Leading Sources of Pollution Impairing the Great Lakes Shoreline Waters.

Level of Pollution	**Major**	**Moderate/ Minimum**	**Not Specified**	**Total**
	Shoreline Miles Impaired			
Atmospheric Deposition	0	1,068	0	1,068
Discontinued Discharges	1,017	0	0	1,017
Contaminated Sediment	684	65	0	749
Land Disposal	20	438	0	458
Unspecified Nonpoint	196	100	0	296
Agricultural	8	218	0	226
Urban Runoff/Storm Sewers	15	189	0	204
Industrial Point Sources	0	204	0	204
Municipal Point Sources	1	19[illegible]	0	192
Combined Sewer Overflows (CSOs)	21	151	0	172
Onsite Wastewater Systems	69	27	0	96
Spills and Illegal Dumping	0	84	0	84
Streambank Destabilization	0	59	0	59
Construction	6	42	0	38
In-Place Contamination	0	33	0	33
Contaminated Groundwater	0	20	0	20

Agricultural activities have further been identified as a leading source of pollution that impairs use of the Great Lakes shoreline waters. These sources of impairments are shown in the following table. Agriculture is the sixth major cause of these impairments when ranked according to the number of shoreline miles impaired. There are a total of 5,559 total Great Lakes shoreline miles in the Nation. Of that total, 5,224 miles were surveyed and 5,077 miles were determined to be impaired.

The USGS continues to evaluate nitrate concentrations on a national basis, and the 1994 EPA report summarizes the results of an analysis of about 12,000 samples. The report states:

> The analysis indicated that about 50 percent of the wells were characterized by elevated levels or nitrate (levels that exceeded 3 mg/l, which is typically held as the threshold indicating human impacts)...Samples collected from agricultural areas had significantly higher nitrate concentrations than other land use settings, with 16 percent of the samples exceeding the maximum contaminant level (MCL)...nitrate concentrations exceeding the MCL were most frequently detected in irrigation and stock wells as opposed to private and public water supply wells.

WILDLIFE AND WILDLIFE HABITAT

Grassland Birds

Prior to the 1950's, the relatively low intensity of land use, small amounts of new land brought into production, and the intrinsic diversity of most agricultural operations led to few conflicts between agriculture and the survival of wildlife populations associated with agricultural ecosystems. The comparatively low intensity of agricultural land use, combined with the affects of smaller farms that maintained pasture for livestock, fostered sufficient diversity in vegetation and land use to permit sufficient habitat to allow survival of game and nongame wildlife species. The growing intensity of agriculture in the 1960's, combined with declining numbers of individual farms and greater reliance on off-farm inputs, particularly chemical fertilizers and pesticides, began a period of significant losses in the amount and quality of wildlife habitat associated with agricultural ecosystems. As the demand for and value of market crops increased, the amount of land in multiple use declined, reflecting a greater dependance on fewer types of crops grown and growing efforts to bring more environmentally sensitive land into production. The implications for wildlife associated with agricultural landscapes was a decline in the amount, quality, and distribution of habitat needed to sustain wildlife populations.

Further response to growing demands for grain during the 1970's brought even more new lands into production, particularly in the Great Plains States. Combined with the continuing trend in consolidation of individual farms and fields, grassland dependent species were subjected to losses of habitat necessary for their survival. Those tracts of grasslands that remained out of production were typically small and, viewed from a landscape scale, isolated within a countryside dominated by intensive production of grain crops. Consequently,

wildlife species that evolved specifically within Great Plains grasslands began a decline in number and distribution that continued though the first half of the 1980's. The populations of avian species endemic to the Great Plains have declined more than populations of avian species associated with other North American vegetation associations (Knopf 1995, Johnson and Koford 1995). Agriculturally related activities with universal negative effects on habitats for these species include transformation of native grasslands to cropland, fragmentation of grasslands, and drainage of wetlands (Knopf 1995, Igl and Johnson 1995). Development of woody vegetation associated with changes in hydrologic regimes on major rivers and following suppression of wildfires in eastern and central plains regions further altered the physical composition of grasslands, permitting emigration of non-endemic grassland species, thereby, further impacting grassland birds through competition for remaining habitat, higher rates of predation, and nest parasitism.

Of 11 endemic species identified by Knopf's North American Breeding Bird Survey data (1995) indicate that populations of 7 of these species were declining during the 1966 to 1979 period (Table 3.11). This period roughly corresponds to intensification of small grain and row crop production and relatively large acreages in U.S. Department of Agriculture annual set-aside programs. During this period the average annual amount of land in annual set aside was 23.92 million acres (min = 0, max = 56.7 million acres) (Berner 1989). Typically, one-

Table 3.11. Population Trends of Avian Species Endemic to the Great Plains Grasslands Based on U.S. Fish and Wildlife Service Breeding Bird Survey Data.

	Population trends 1966-1995 U.S. Fish and Wildlife Service Region 6 1/, 2/	
	1966-1979	1980-1995
Ferruginous hawk	2.6	13.6
Mountain plover	0.7	1.5
Long-billed curlew	1.2	-3.2
Marbled godwit	9.7	2.7
Wilson's phalarope	-5.1	1.4
Sprague's pipit	-7.6	1.3
Cassen's sparrow	-8.5	3.4
Baird's sparrow	-4.2	-1.1
Lark bunting	-4.1	0.6
McCowans longspur	5.8	3.6
Chestnut collared longspur	0.8	-0.8

1/ USFWS Region 6 includes Montana, North Dakota, South Dakota, Wyoming, Nebraska, Colorado, and Kansas.
2/ Values represent a positive (+) or negative (-) change in population estimates per year of the survey period.

year set-aside programs yielded only small benefits to wildlife and could actually diminish habitat quality associated with agriculture due to failure to provide adequate nesting and winter cover. Regulations pertaining to the management of this acreage further aggravated the situation by allowing late seeding and mandatory destruction by mowing, disking or plowing of cover on retired acres during the nesting season, and severely limited the contribution of these programs in providing wildlife habitat.

Waterfowl

Increased intensity of agricultural production has had major impacts on waterfowl populations in the Great Plains region as well. Changes in waterfowl populations are affected largely by long-term fluctuations in the quality and distribution of cover, water regimes, and forage resources. Long-term declines in populations of some duck species have been most affected by habitat conditions on the northern breeding grounds (Caithamer and Smith 1995). Although yearly trends in precipitation that influence abundance and diversity of wetland types affect some duck populations, most dabbling ducks require the presence of high-quality grass dominated cover for successful reproduction.

The mallard has the most extensive breeding distribution of any duck in North America. However, the Prairie Pothole Region, extending from northern Montana across the Dakotas to western Minnesota, has supported about 56 percent of the North American mallard breeding population since 1960 (Ducks Unlimited 1994).

The estimated breeding population of mallards in North America has ranged from 11 million in 1958 to less than 5 million in 1985 (Figure 3.8). As of 1993, the mallard breeding population was 29.7 percent below the mean 1970's population estimate (Ducks Unlimited 1994).

Mallard numbers and recruitment rates[1] in northern Canada, Alaska, and the northwestern United States have remained stable, or increased, while reproductive success has declined in the more intensively farmed Prairie Pothole region (Ducks Unlimited 1994). Research has attributed declines in mallard populations within the Prairie Pothole Region to intensified agricultural land use resulting in declines in wetland abundance and diversity and lower reproductive success (Department of the Interior 1988, Ducks Unlimited 1994, Shaffer and Newton 1995). Agriculturally related impacts to habitat include losses of seasonal and ephemeral wetlands, diminished amounts of suitable nesting cover, increased mortality of nesting hens, later hatching of successful nests, and poor survival of ducklings (Sargeant et al. 1993, Shaffer and Newton 1995). Changes in habitat quality and distribution within the Prairie Pothole Region on mallard populations typify the effects of agricultural land use on other waterfowl species that have comparable habitat needs.

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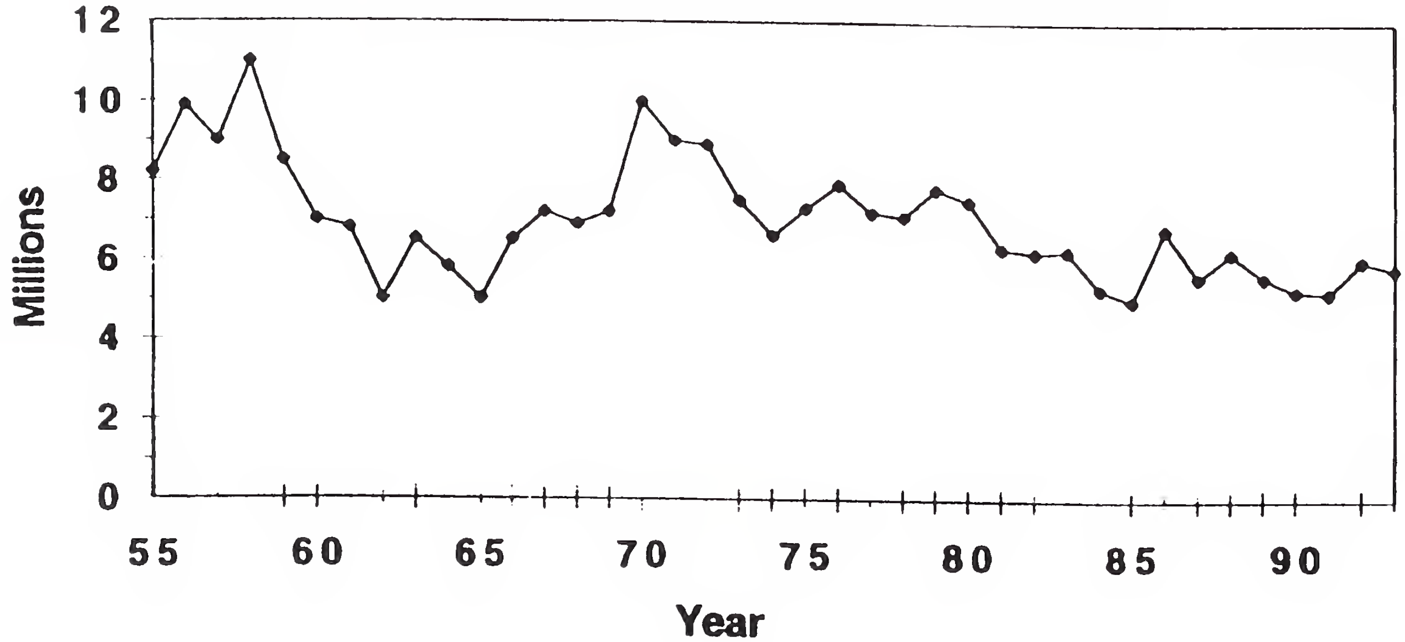
[1]The recruitment rate is defined as the number of young female mallards that enter the fall population per adult female in the spring population.

Figure 3.8

Trends in Mallard Breeding Population from 1955-93
Modified from Ducks Unlimited 1994



Farmland Wildlife

The intensification of land use has significant effects on wildlife traditionally associated with agriculture. The loss of rarely farmed idle areas and pastures, larger fields, monocultures, and a lower diversity in the types of crops produced have diminished the ability of agricultural landscapes to provide year-to-year habitat and long-term support for populations of both game and non-game wildlife.

Comparison between the amount of land in annual and long-term set-aside programs illustrates the effects of these policies on a common farmland species, the ring-necked pheasant. A national summary of acres in long-term (primarily the Soil Bank) and various short-term set-asides between 1945 and 1983 is illustrated in Figure 3.9. Although the set-aside data are summarized nationally, trends in pheasant populations in Minnesota (A. Berner, personal communication, Minnesota Department of Natural Resources, Madelia) and South Dakota (S. Riley, personal communications, S. Dakota, Game, Fish and Parks Department, Pierre) show comparable responses. The numbers of birds observed on 100 mile survey routes in Minnesota and the estimated pre-hunting population in South Dakota demonstrate a positive response to long-term set-aside programs. In contrast the numbers of birds observed declined during those years with the greatest amount of land in annual set-aside programs.

Although establishment of long-term cover under the CRP has generally provided favorable habitat to wildlife associated with agriculture, other activities continue to impact wildlife associated with intensive production of agricultural crops. Research in Kansas (R. Rogers, personal communication, Kansas Department of Wildlife and Parks, Hays) and elsewhere indicate that intensive measures to control weeds and declining height of grain stubbles have prevented pheasant populations from responding to the high-quality cover provided by the CRP. Undoubtedly, the absence of CRP grasslands over the last 10 years would have contributed to even greater declines in pheasant populations as well as other species dependent upon an interspersion of idle cover with land in active production of crops.

WETLANDS

At the time of Colonial America, the area that now constitutes the 50 United States contained an estimated 392 million acres of wetlands (Table 3.13) (Dahl and Johnson 1991). Of this total, 221 million acres were located in the lower 48 States. Another 170 million acres occurred in Alaska. Hawaii contained an estimated 59,000 acres of wetlands.

Over the next 200 years, the lower 48 States lost an estimated 53 percent of their original wetlands. Alaska has lost only a fraction of 1 percent, while Hawaii has lost an estimated 12 percent of its original wetlands. A total of 22 States have lost 50 percent or more of their original wetlands. California has lost the largest percentage of original wetlands within the State (91 percent). Florida has lost the most acreage (9.3 million acres).

Figure 3.9 Comparison between the amount of land in annual and long-term set aside programs and estimates of ring-necked pheasant abundance in Minnesota (Fig. 2a) and South Dakota (Fig. 2b).

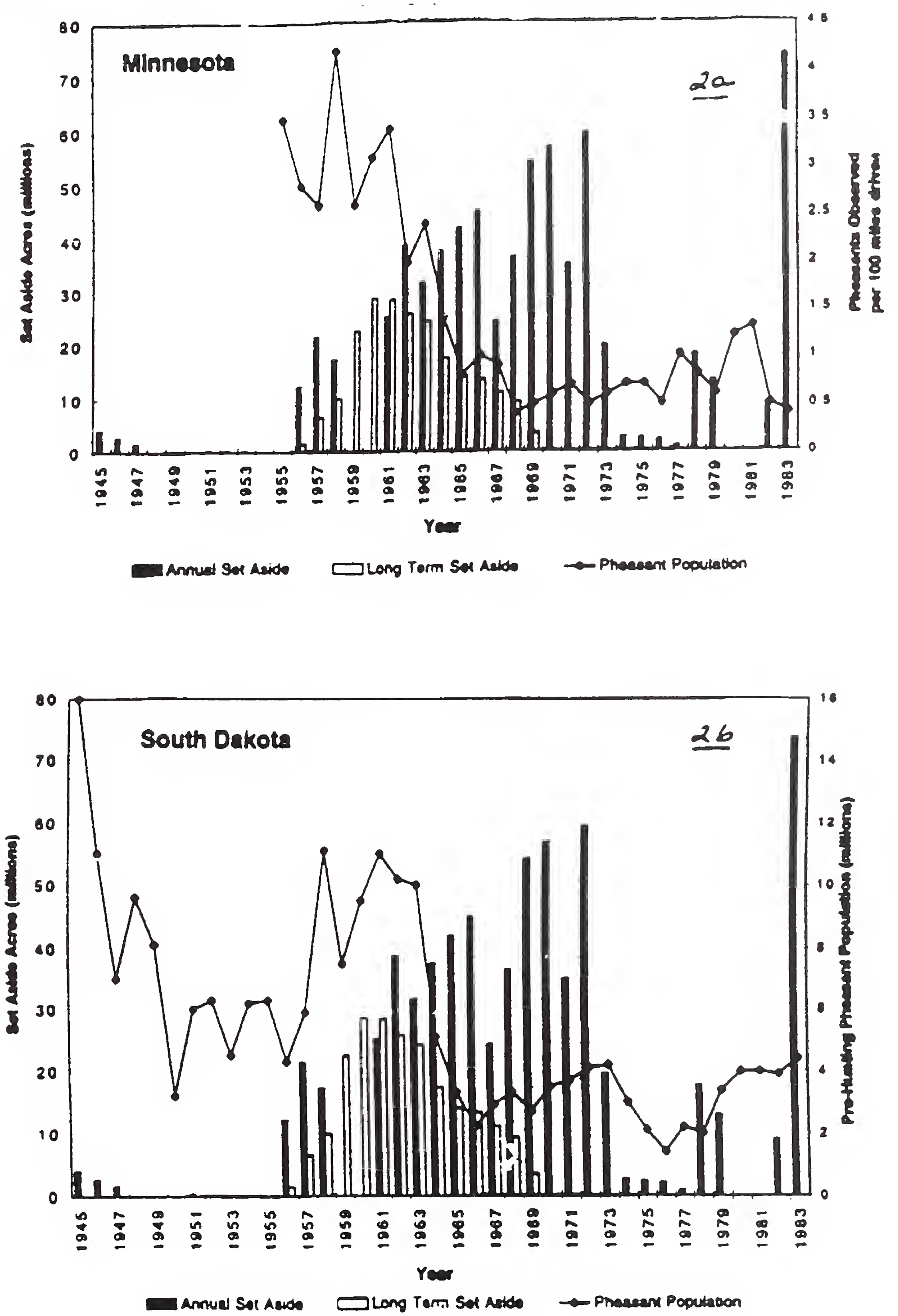


Table 3.13

WETLAND LOSSES IN THE UNITED STATES 1780'S TO 1980'S (ACRES)

STATE	TOTAL SURFACE AREA	ESTIMATES OF ORIGINAL WETLANDS CIRCA 1780'S	PERCENT OF SURFACE AREA	ESTIMATES OF EXISITNG WETLANDS CIRCA 1980'S	PERCENT OF SURFACE AREA	PERCENT OF WETLANDS LOST
CT	3,205,760	670,000	20.9	172,500	5.4	74
DE	1,316,480	479,785	36.4	223,000	16.9	54
MA	5,284,480	818,000	15.5	588,486	11.1	28
MD	6,769,280	1,650,000	24.4	440,000	6.5	73
ME	21,257,600	6,460,000	30.4	5,199,200	24.5	20
NH	5,954,560	220,000	3.7	200,000	3.4	9
NJ	5,015,040	1,500,000	29.9	915,960	18.3	39
NY	31,728,640	2,562,000	8.1	1,025,000	3.2	60
PA	29,013,120	1,127,000	3.9	499,014	1.7	56
RI	776,960	102,690	13.2	65,154	8.4	37
VT	6,149,760	341,000	5.5	220,000	3.6	35
Northeast	116,471,680	15,930,475	13.7	9,548,314	8.2	40
KY	25,852,800	1,566,000	6.1	300,000	1.2	81
NC	33,655,040	11,089,500	33.0	5,689,500	16.9	49
TN	27,036,160	1,937,000	7.2	787,000	2.9	59
VA	26,122,880	1,849,000	7.1	1,074,613	4.1	42
WV	15,475,840	134,000	0.9	102,000	0.7	24
Appalachia	128,142,720	16,575,500	12.9	7,953,113	6.2	52
AL	33,029,760	7,567,600	22.9	3,783,800	11.5	50
FL	37,478,400	20,325,013	54.2	11,038,300	29.5	46
GA	37,680,640	6,843,200	18.2	5,298,200	14.1	23
SC	19,875,200	6,414,000	32.3	4,659,000	23.4	27
Southeast	128,064,000	41,149,813	32.1	24,779,300	19.3	40
AR	33,986,560	9,848,600	29.0	2,763,600	8.1	72
LA	31,054,720	16,194,500	52.1	8,784,200	28.3	46
MS	30,538,240	9,872,000	32.3	4,067,000	13.3	59
Delta States	95,579,520	35,915,100	37.6	15,614,800	16.3	57
IA	36,025,600	4,000,000	11.1	421,900	1.2	89
IL	36,096,000	8,212,000	22.8	1,254,500	3.5	85
IN	23,226,240	5,600,000	24.1	750,633	3.2	87
MO	44,599,040	4,844,000	10.9	643,000	1.4	87
OH	26,382,080	5,000,000	19.0	482,800	1.8	90
Corn Belt	166,328,960	27,656,000	16.6	3,552,833	2.1	87
MI	37,258,240	11,200,000	30.1	5,583,400	15.0	50
MN	53,803,520	15,070,000	28.0	8,700,000	16.2	42
WI	35,938,560	9,800,000	27.3	5,331,392	14.8	46
Lake States	127,000,320	36,070,000	28.4	19,614,792	15.4	46
KS	52,648,960	841,000	1.6	435,400	0.8	48
ND	45,225,600	4,927,500	10.9	2,490,000	5.5	49
NE	49,425,280	2,910,500	5.9	1,905,500	3.9	35
SD	49,310,080	2,735,100	5.5	1,780,000	3.6	35
Northern Plains	196,609,920	11,414,100	5.8	6,610,900	3.4	42
OK	44,748,160	2,842,600	6.4	949,700	2.1	67
TX	171,096,960	15,999,700	9.4	7,612,412	4.4	52
Southern Plains	215,845,120	18,842,300	8.7	8,562,112	4.0	55
AZ	72,901,760	931,000	1.3	600,000	0.8	36
CO	66,718,720	2,000.000	3.0	1,000,000	1.5	50
ID	53,470,080	877,000	1.6	385,700	0.7	56
MT	94,168,320	1,147,000	1.2	840,300	0.9	27
NM	77,866,240	720,000	0.9	481,900	0.6	33
NV	70,745,600	487,350	0.7	236,350	0.3	52
UT	54,346,240	802,000	1.5	558,000	1.0	30
WY	62,664,960	2,000,000	3.2	1,250,000	2.0	38
Mountain	552,881,920	8,964,350	1.6	5,352,250	1.0	40
CA	101,563,520	5,000,000	4.9	454,000	0.4	91
OR	62,067,840	2,262,000	3.6	1,393,900	2.2	38
WA	43,642,880	1,350,000	3.1	938,000	2.1	31
Pacific	207,274,240	8,612,000	4.2	2,785,900	1.3	68
SUBTOTAL	1,934,198,400	221,129,638	11.4	104,374,314	5.4	53
AK	375,303,680	170,200,000	45.3	170,000,000	45.3	0
HI	4,115,200	58,800	1.4	51,800	1.3	12
TOTAL U.S.	2,313,617,280	391,388,438	16.9	274,426,114	11.9	30

The data presented here and in Table 3.13 must be interpreted in the appropriate context. The estimated percentage of wetland loss for an individual State must be evaluated relative to the total estimated surface acreage of the State, the 1780's total estimated wetland acreage of the State, and the 1980's estimated wetland acreage. For instance, California has a total surface area of approximately 101 million acres. It is estimated that in the 1780's California had 5 million acres of wetlands, or approximately 5 percent of California's total acreage was considered wetlands. It is now estimated that California has less than 500,000 wetland acres remaining. This estimate represents a wetlands loss of 91 percent of the 1780's estimated acreage, but also means that currently less than one-half of 1 percent of California's total acreage is wetlands.

The rate of wetland loss has decreased significantly over the last 20 years (Figure 3.10) (USDA 1991). A number of factors played a role in this decrease. Starting in 1986, USDA implemented the wetland conservation provisions of the Food Security Act of 1985. These provisions deny farmers eligibility to Federal agricultural program benefits if they convert wetlands to agricultural uses. At about the same time, commodity prices were depressed, decreasing the potential returns from draining wetlands. Further, the vast majority of easily converted wetlands have already been drained and the remaining wetlands are either costly to convert to agricultural production or would not result in highly productive agricultural land.

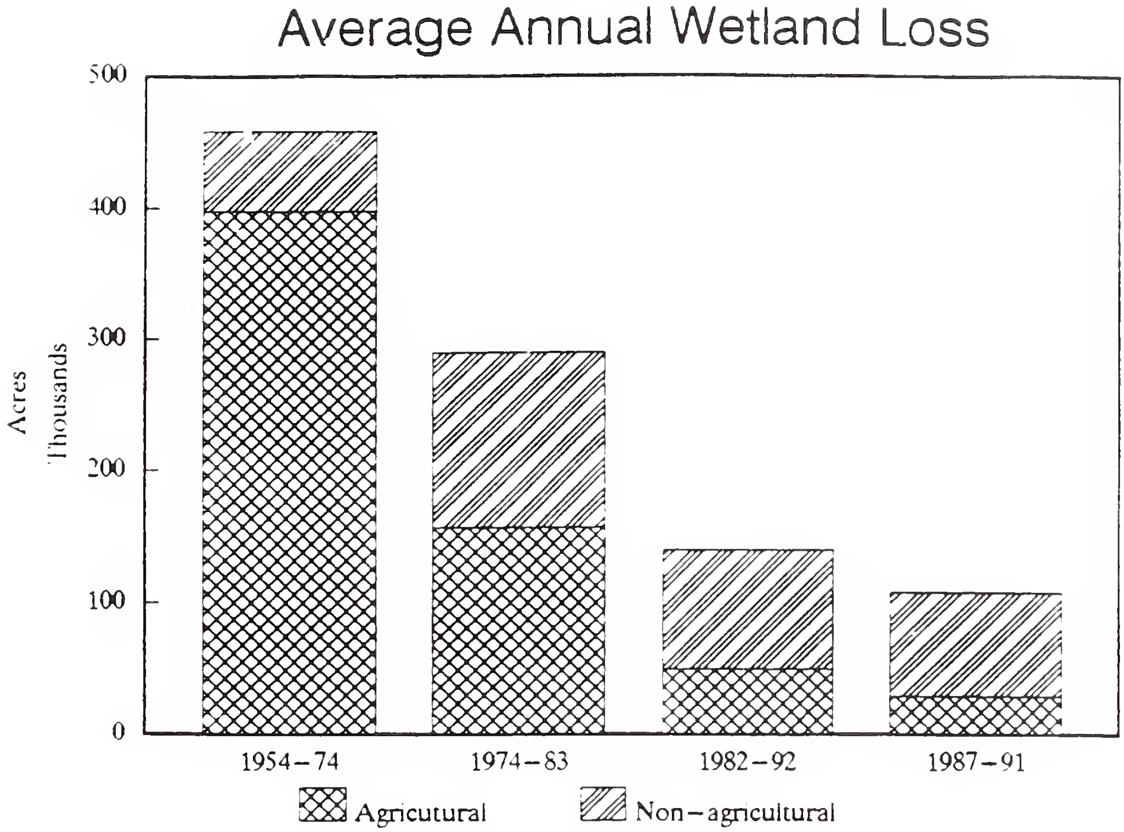
Over the entire time period from the 1780's to the 1980's, average wetland losses are estimated at 585,000 acres per year. From 1954 to 1974 an average of 458,000 acres were lost each year with agriculture accounting for 87 percent of the losses. From 1974 to 1983, average annual losses were 290,000 acres with agriculture accounting for 54 percent of the losses. From 1982 to 1992 average annual losses decreased to 140,000 acres with agriculture accounting for 36 percent of the losses, about 50,000 acres per year. The most recent data for 1987 to 1991 show that average losses have decreased to 108,000 acres per year, with agriculture accounting for only 27 percent of the losses, 29,500 acres per year.

All the estimates of wetland acreage and losses do not differentiate between losses due to drainage, land leveling, or sedimentation. In addition, the status of wetland functions and the corresponding values generated by the wetlands are not estimated. It is not known to what extent remaining wetlands are degraded or whether the remaining wetlands are providing proportionally larger values that partially offset those no longer being provided by converted wetlands.

Wetland functions include:

- Habitat for migratory birds and other wildlife, particularly at-risk and threatened and endangered species.
- Protection and improvement of water quality.
- Attenuation of water flows due to floods.
- Recharge of ground water.
- Protection and enhancement of open space and aesthetic quality.

Figure 3.10


Average Annual Wetland Loss
500
400
300
200
100
0
Acres
Thousands
1954-74
1974-83
1982-92
1987-91
Agricutural
Non-agricultural

- Protection of flora and fauna which contributes to the Nation's natural heritage and biodiversity.

The following subsections provide a brief overview of the nature of wetland benefits.

Wildlife Habitat

One of the most widely discussed benefits of wetlands is providing feeding, reproductive, and cover habitat for wildlife. Three-fourths of North America's birds depend upon wetlands for resting, feeding or nesting (Steinhart 1990). Wetlands in the North Central and Northeastern United States provide habitat for more than 200 migratory and resident bird species in addition to other species such as beaver and moose (Williams 1981). Salt marshes provide spawning grounds and nurseries for fish and flyways for birds (Reed 1984). Two-thirds of the commercial fish and shellfish harvest come from species that depend on wetlands for all or part of their life cycles (Steinhart 1990). Shallow basin seasonal and semi-permanent prairie wetlands represent the principal breeding habitat for North American waterfowl (Kaminski and Weller 1992). Prairie wetlands provide critical breeding and migratory habitat for over 100 species of birds (e.g., waterfowl, shorebirds and passerines) and on a per area basis support the greatest number and variety of wildlife of any biological community on the continent (Pendelton and Brasher, undated).

Water Quality

Wetlands also retain and remove nutrients from surface runoff. Stream, lake, and reservoir water quality in the Midwest can be degraded by nutrients from agricultural runoff. A 4-year study (1976-79) of Eagle Lake Marsh, Iowa, showed that the marsh serves as a sink for nitrogen and phosphorous (Davis et al. 1981). The ability of a wetland to retain nutrients depends on conditions of the wetland over time, the balance between water inflow and outflow, the retention time of surface water, and numerous physical and chemical processes (Neely and Baker 1989).

Downstream Flood Damage Reduction

Wetland areas can contribute to regulating flood flows from major summer storms and spring snow melt (Larson 1981). Flood control attributable to a wetland site varies according to outlet capacity, storage availability within the site, and the amount of water entering the wetland (Kittelson 1988). Although the effects of wetlands on flooding varies from watershed to watershed, Larson's study demonstrated that drainage of wetlands significantly increased both the annual runoff and the volume of storm runoff.

Ground Water Recharge

Wetlands also function as ground water recharge and discharge areas. Linder and Hubbard found the roles that wetlands play in recharging aquifers in the Prairie Pothole region are

complex and the relationships of wetlands to the underlying aquifers are not well understood. However, research has shown a close interaction between ground water and lakes and wetlands (Winter 1989). In some instances, the water table slopes away from the wetland and ground water recharge occurs. In other instances, the water table slopes into the wetland and ground water discharge occurs. In most wetlands, both situations occur and the wetlands provide functions of both recharge and discharge (Winter 1989). If recharge occurs at a greater rate than discharge, the wetland is valuable in maintaining or increasing ground water supply. However, the recharge-discharge function of wetlands is so site specific that generalizations cannot be made (Siegel 1988).

AIR QUALITY

When wind blows across soil and over fields, picking up and carrying along soil and other particulates such as crop residues, or carries away pesticides or nitrates from fertilizers, air quality may be impaired. In the United States, wind erosion on cultivated cropland occurs at a rate of nearly 1 billion tons of soil annually, which in addition to reducing productivity and damaging crops, also causes air quality problems (USDA 1995). Wind can also transport residues from pesticide and fertilizer applications on cropland for long distances, either as part of soil particulates or by themselves.

Tillage of cropland, which can periodically leave the soil surface devoid of protective vegetative cover or structural features and susceptible to wind erosion, is a major source of fugitive dust in specific regions of the country, particularly in the west, where there is lower rainfall, frequent droughts, high wind velocities, and many light, sandy soils.

The U.S. EPA has determined that particles smaller than 10 microns in diameter (PM_{10}) are dangerous to human health, and has established standards for air quality based on this criteria.

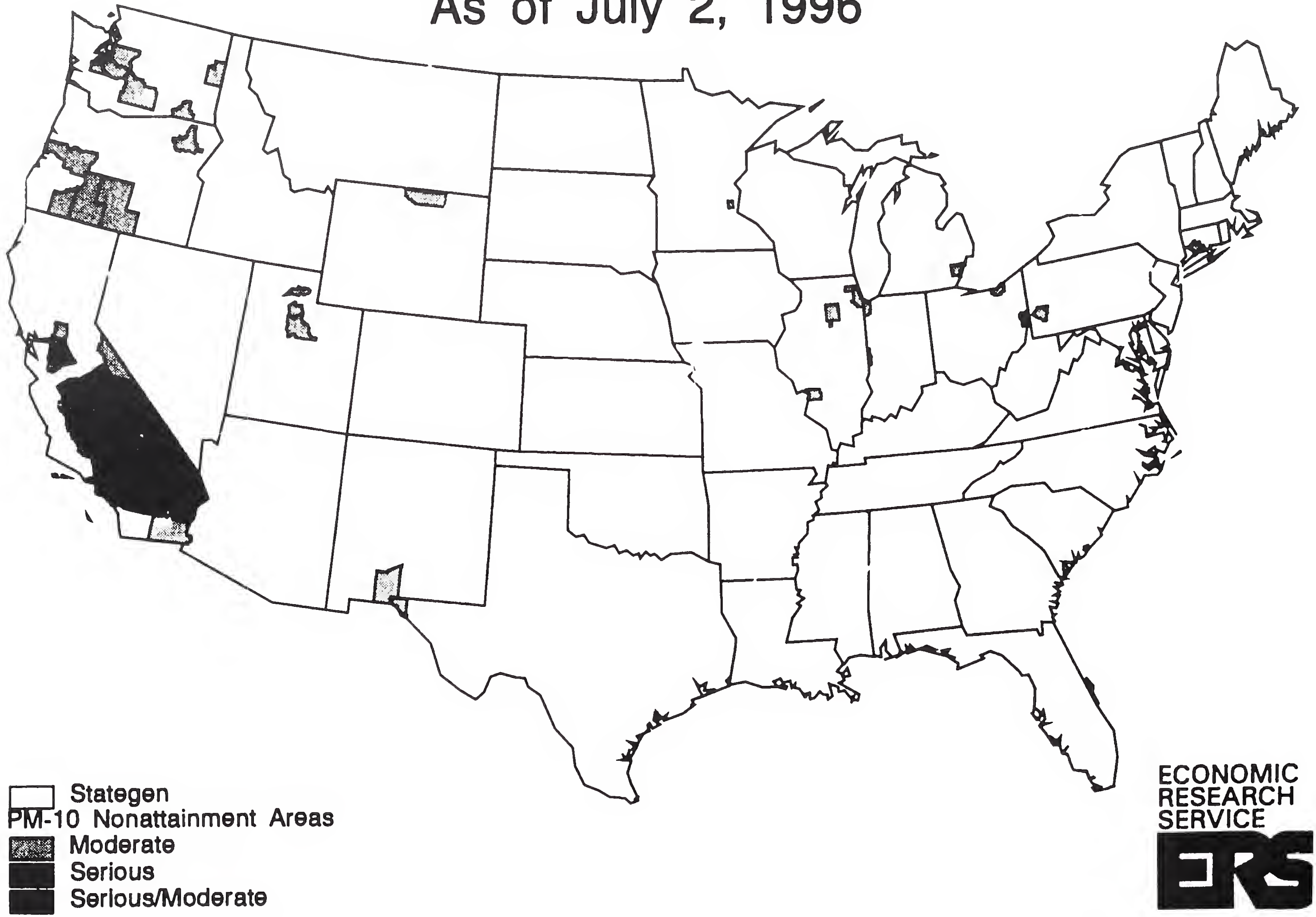
Studies have indicated that windblown soil sediments contain significant amounts of material of 10 microns and smaller (Ervin and Lee 1994). However, little is currently known of the extent that wind erosion from cropland contributes to fugitive dust, and the emission of PM_{10} material from cropland as a result of wind erosion processes is not predictable with currently available models (Saxton 1996).

Windblown dust can exacerbate respiratory problems in humans and animals; permeate homes, offices, factories, and machinery; reduce visibility for surface and air transportation; and when accumulating on plant leaves, reduce quality and growth of plants (USDA 1989).

Comprehensive assessments of the Nation's air quality and of the impacts of crop production practices on air quality are not currently available. However, EPA tracks air quality and reports areas not meeting established standards, "non-attainment" areas (Figure 3.11). Except for eastern Washington, these areas generally do not coincide with areas where large amounts of wind erosion from cropland is occurring (see Figure 3.2). Agricultural production practices have been determined by EPA to significantly contribute to particulate air pollution in many

Figure 3.11

EPA PM-10 Nonattainment Areas As of July 2, 1996



areas of the arid west, including the San Joaquin area of California, the Las Cruces area of New Mexico, and the Lubbock area of Texas (Ribaudo et al. 1990). The Southern High Plains area of Texas, including the Lubbock area, has extremely high wind erosion rates and dust storms are a frequent occurrence (Ervin and Lee 1994).

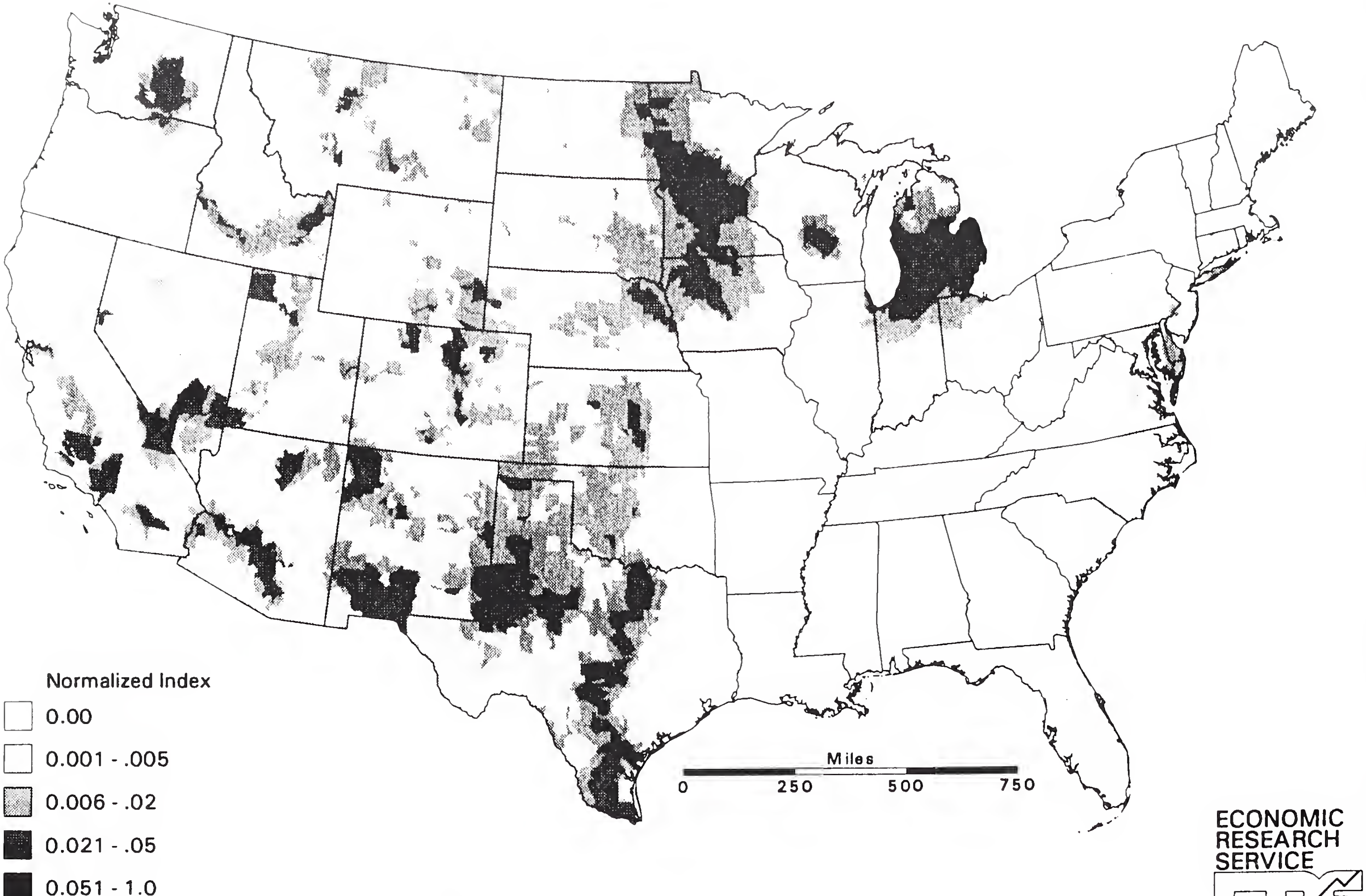
In the Pacific Northwest and throughout other areas in the western U.S., many soils are very susceptible to wind erosion. These soils are a mixture of loess (windblown silt), volcanic ash, and glacial outwash, and are often moderately sandy with some very fine particulates but low organic matter (Saxton 1996). As a result, as much as 4 percent of the surface material may freely exist as particles of 10 microns or less, compared with about 0.25 percent in midwestern U.S. soils.

Weighting wind erosion from cropland by population in the prevailing downwind direction shows where wind erosion is likely to have the greatest impact on people and their possessions (Figure 3.12). Areas where crop production and downwind population coincide include large areas of Michigan, central Minnesota, northwest Iowa and northeast Nebraska and the Lubbock area of Texas, and eastern Washington. This does not mean that there are not other areas where significant amounts of wind erosion is occurring and affecting air quality, just that there may not be relatively large population centers nearby.

Particulate air pollution can be damaging to human health, and at commonly occurring levels, is associated with a range of adverse outcomes, including premature death (Schwartz 1991). Numerous studies have found mortality from lung cancer and cardio-pulmonary disease to be associated with fine-particulate air pollution (Dockery et al. 1993). However, it is not reported to what extent windblown dust from cropland may be contributing to fine-particulate air pollution in cities, where these studies have been conducted, and where urban air pollution, including factories and automobiles, are believed to be the significant contributor to the reported health problems.

Figure 3.12

Population affected by Cropland Wind Erosion, 1992



Created by Vince Breneman 01/23/97

IV. RISK CHARACTERIZATION

This risk characterization presents information that will be useful in making decisions about the identity and location of the types of cropped acreage that should receive priority for enrollment in CRP. The acreage selected for enrollment and the cover practices established on those acres should be the best available to address the environmental endpoints defined in and by the CRP authorizing legislation: (1) soil productivity, (2) water quality, (3) wildlife habitat, (4) wetlands, (5) and air quality. In addition, the specific intent of Congress with regard to the operation and management of CRP and the other components of the conservation provisions of the 1996 Act is that they be carried out in an efficient and cost-effective manner.

This risk characterization will identify and, when possible quantify, the specific stressor and/or impact situations that, when addressed through the long-term land retirement possible under CRP, should begin to improve the environmental conditions associated with the endpoints.

The specific environmental stressor/impact situations that will be the focus of the risk characterization include (1) soil erosion and soil productivity, (2) sedimentation, nutrient and pesticide use, and water quality, (3) cropped wetlands, (4) wildlife habitat, habitat problem and priority areas, (5) wind erosion and air quality.

RECOVERY TIME SCALES

For most resources, complete ecological recovery will take many years and decades. For some, especially endangered and threatened species, recovery may never occur. For most problems, however, recovery can begin almost immediately on CRP acreage (all other conditions remaining constant) because the program offers the direct and unique opportunity to completely eliminate most of the cropping and other farm production actions previously occurring on the acreage that contributed to the adverse affects on the impacted resources.

For example, once cover crops are established on land enrolled in CRP, erosion falls to extremely low levels, essentially stopping its negative effects on soil productivity, water quality (sediment), and air quality (particulate matter). Likewise, conversion of cropland to permanent wildlife habitat should begin to alleviate habitat capacity and predation constraints that existed when the enrolled acreage was actively cropped. Similarly, enrollment of cropped wetlands into the program should permit these wetlands to resume many of their original wetland functions. (The extent to which this occurs depends on the extent the wetland has been altered through cropping from its original condition.) In this respect, CRP (or any similar long-term land retirement or land-use conversion program) is unique. Most other types of conservation programs require the application of practices or management systems that must accomplish environmental objectives while allowing continued cropping activity. This clearly illustrates the major benefit (or constraint) of CRP for addressing environmental concerns. By its very nature (i.e., long-term land conversion) it has the potential to be very effective in addressing certain environmental stressor and impact situations. On the other

hand, it generally requires that the individual land owner or farm or ranch operator cease activities that provide food and fiber for consumers and income to themselves. The cost to the individual landowner is significant and should be reimbursed by the public sector. The relatively high cost of such an approach to solving conservation problems means that long-term conversion must be reserved for those situations that cannot be adequately addressed with lessor measures. Thus, cropland selected for enrollment in CRP must be that land on which cropping must be terminated in order to achieve the desired environmental objective. Enrollment of cropland in CRP should be viewed as the conservation management practice of last resort.

CHRONICLE OF UNCERTAINTIES

Activities undertaken for crop production form a very interdependent and complex system of cause and effect linkages with the natural resource base, including feedback mechanisms and buffers. Often, there are long and varying time lags associated with the occurrence of an event or activity and its impact on one or more elements of the resource base. Also, because of the large and diffuse set of cropping activities and farming operations, it is difficult to trace the impacts back to the original source. Further, similar environmental impacts can be caused by non-agricultural activities, e.g., point source pollutants, and isolating the specific cause and impact relationships is often very difficult. Finally, other factors that are clearly outside the control of farm producers, such as weather and market forces, further complicate the diverse, complex and dynamic set of environmental cause and effect relationships associated with agriculture cropland use.

Because of this incredible complexity and diversity, it has been extremely difficult to establish detailed and consistent databases to empirically describe the stressor-environmental component relationships and their impacts. This information shortfall illustrates the uncertainties associated with supporting the hypotheses established in the assessment. These data limitations and the associated uncertainties are highlighted in the discussion and analysis presented in the assessment.

Although the data available are not sufficiently consistent and complete, they do provide some basics for identifying those situations that are likely best served by a CRP-type program to address the identified endpoints. Often, the information needed to identify and quantify the cropping activity-stressor-impact relationships and guide in the effective and efficient implementation of the program is available at the State and local level rather than at the National level. State and local officials typically have more and better information and better insights on the nature and extent of the situations and appropriate responses in these areas than do national program officials. Incorporation of their input into both the identification and solution of the problems should significantly reduce the uncertainties associated with the development and implementation of program provisions to address the identified CRP endpoints. Thus, the specific uncertainties about the environmental cause-and-effect relationships discussed here may be somewhat overstated and can be significantly reduced if the knowledge and experience of individuals and agencies at the State and local level are

enlisted into the CRP enrollment and management process. The principal contribution of this risk assessment, then, will be to present and combine information that will allow National-level policymakers to generally target the situations and areas where participation in the program is most likely to address the endpoint degradation and work with the States and localities in these areas or with those situations to refine the application of the provisions of the program toward solutions to the identified environmental problems.

EROSION RELATED IMPACTS

Soil Productivity

The large erosion reduction on cropland with the highest erosion rates and the removal of cropland, through the CRP, with excessive erosion rates, has significantly ameliorated the productivity loss problem associated with excess erosion on U.S. cropland. However, productivity losses for certain crops are still significant in some areas of the country (Table 4.1). Productivity losses are averaging more than 3 percent per 100 years for corn in the Northeast and Lake States, with a national average productivity loss of almost 2 percent. Productivity loss on cropland used to grow soybeans in the Lake States is more than twice the national average productivity loss on soybean acreage. Productivity losses on land used to grow wheat appears to be nominal in most areas. The national average productivity loss on land to grow wheat is only 0.5 percent, with the Lake States again having the highest loss, 2.1 percent, and the Southern Plains having the lowest average productivity loss, 0.1 percent.

Over 36.4 million acres of cropland have been removed from production by enrollment in CRP and put under permanent cover. Three-fourths of this land is highly erodible. Over 90 percent of the CRP land enrolled in the Northeast, Appalachian, and the Mountain regions are highly erodible. About half of the lands enrolled in the Lake States are not highly erodible but most of those were eroding greater than T when cropped or are wetlands.

If the CRP lands returned to production, almost 94 percent, or 34.1 million acres, would still erode greater than the rate which could maintain production indefinitely. Almost all of the land in the Southern Plains, 99 percent, would erode greater than T if returned to production. The Northern Plains has the lowest percentage, 84 percent, of CRP lands that would erode greater than T if returned to production.

Only 18 percent of the CRP lands are expected to suffer a productivity loss of at least 2 percent over the next 100 years if returned to crop production. Although many of the CRP lands are expected to erode at higher than average rates if returned to crop production, much of the soils, particularly in the Northern and Southern Plains, are deep enough that productivity loss is not a severe problem for the next 100 years.

Table 4.1. Yield Reduction from 100 years of Soil Erosion on Cropland, 1992

Production Region	Yield Reduction by Crop: Corn	Soybeans	Cotton	Wheat
		percent		
Northeast	3.5	2.3	*	2.0
Appalachia	1.7	1.7	2.1	1.2
Southeast	0.6	1.1	1.7	0.6
Delta States	0.8	0.7	1.0	0.4
Corn Belt	1.4	1.2	*	0.7
Lake States	3.2	3.0	*	2.1
Northern Plains	1.4	1.0	*	0.3
Southern Plains	0.3	*	2.3	0.1
Mountain	1.1	*	*	1.0
Pacific	*	*	*	0.5
United States	1.8	1.4	1.5	0.5

*Not estimated due lack of acres within region.

Sediment

Cropping practices sometimes result in soil and other agricultural pollutants reaching water bodies and adversely affecting the aquatic environments and related terrestrial plant and animal life. Sediment, the most pervasive pollutant of surface waters, is a widespread consequence of crop production activities. Sediment washing off cropland into waterways can fill reservoirs, block navigation channels, interfere with water conveyance systems, damage aquatic plant life, and impair recreational resources. Annual water quality damages caused by soil erosion from cropland have been estimated at $2.2 billion annually in 1980 (Clark et al. 1985).

Because most soil exiting a field gets trapped in field depressions or natural buffer zones and does not reach a water body, only a portion of the soil erosion that occurs annually translates into sediment delivery to water. Based on estimated sediment delivery ratios, annual sediment from cropland would total about 350 million tons, assuming no CRP, representing about 29 percent of the 1.2 billion tons of sheet and rill erosion occurring annually on cultivated cropland (Table 4.2). About 37 percent of the sedimentation occurs in the Corn Belt (Table 4.3). Other regions with significant sedimentation from cropland include the Northern Plains region with 17 percent and the Appalachian region with 11 percent.

Airborne Dust

Airborne soil from wind erosion can result in increased respiratory problems in humans, reduced visibility from dust-induced haze, and increased household and business maintenance and cleaning costs. Many areas designated as "non-attainment" areas because of concentrations of fugitive dust have repeatedly exceeded Federal health standards. Recent State and Federal attention has focused on PM_{10} material (particulate matter less than 10 μm in diameter). However, little is currently known of the extent that wind erosion from cropland contributes to fugitive dust, and the emission of PM_{10} material from cropland as a result of wind erosion processes is not predictable with currently available data or models (Saxton 1996).

Wind erosion, resulting from crop production practices, is estimated to total about 938 million tons per year, assuming no CRP (Table 4.3). About 75 percent of the wind erosion occurs in the Great Plains and Mountain regions. Wind erosion is also high in parts of the Pacific region (the Columbia Plateau region, mainly southeast Washington), where cities of the area have experienced PM_{10} levels in excess of allowable daily averages on numerous occasions (Saxton 1996). The southern high plains region of Texas has extremely high wind erosion rates and dust storms are a frequent occurrence (Ervin and Lee 1994).

WILDLIFE HABITAT

While agricultural land use has had negative effects on many species, farming provides indispensable components of habitat for others. Agricultural practices and policies that

Table 4.2. Cultivated Cropland: Acreage and Erosion Levels 1/

Region	All Cultivated Cropland		Cropland Eroding > T		EI>=8
	Acres (Million)	Tons/Yr (Million)	Acres (Million)	Tons/Yr (Million)	Acres (Million)
Northeast	10.6	47	4.0	25	4.3
Appalachian	16.3	104	6.9	59	5.9
Southeast	12.6	59	4.8	22	1.8
Delta	19.1	75	5.1	19	1.5
Corn Belt	86.7	448	31.4	196	19.6
Lake States	37.4	244	18.7	118	4.8
No. Plains	88.0	384	28.6	145	22.8
So. Plains	40.4	333	16.7	206	13.8
Mountain	36.0	352	22.0	229	24.2
Pacific	16.5	91	6.4	55	4.3
U.S.	363.6	2,137	144.6	1,074	103.0

1/ Based on 1992 NRI, assuming no CRP.

Table 4.3. Cultivated Cropland: Type of Erosion, Productivity Loss, and Sediment 1/

Region	Sheet and Rill Erosion	Wind Erosion	Productivity Loss>2% 2/	Sediment
	Tons/Yr (Million)	Tons/Yr (Million)	Acres (1,000)	Tons/Yr (Million)
Northeast	46	1	120	19
Appalachian	104	0	630	37
Southeast	59	0	370	17
Delta	75	0	440	25
Corn Belt	407	41	2,470	130
Lake States	98	146	1,250	26
No. Plains	196	188	950	56
So. Plains	94	239	550	22
Mountain	71	281	1,790	12
Pacific	48	42	300	6
U.S.	1,198	938	8,870	350

1/ Based on 1992 NRI, assuming no CRP.
2/ Within 100 years.

maintain mosaics of grass-dominated cover, wetlands, and other small, non-cropped lands interspersed with croplands can provide ideal habitat for numerous species of wildlife. For example, ring-necked pheasants are dependent upon the interspersion of cover and foods provided by agriculture--tilled fields provide high-quality foraging habitat for migrating shorebirds, and the rice fields of the California Central Valley and States located adjacent to the Gulf of Mexico provide crucial foods for wintering waterfowl.

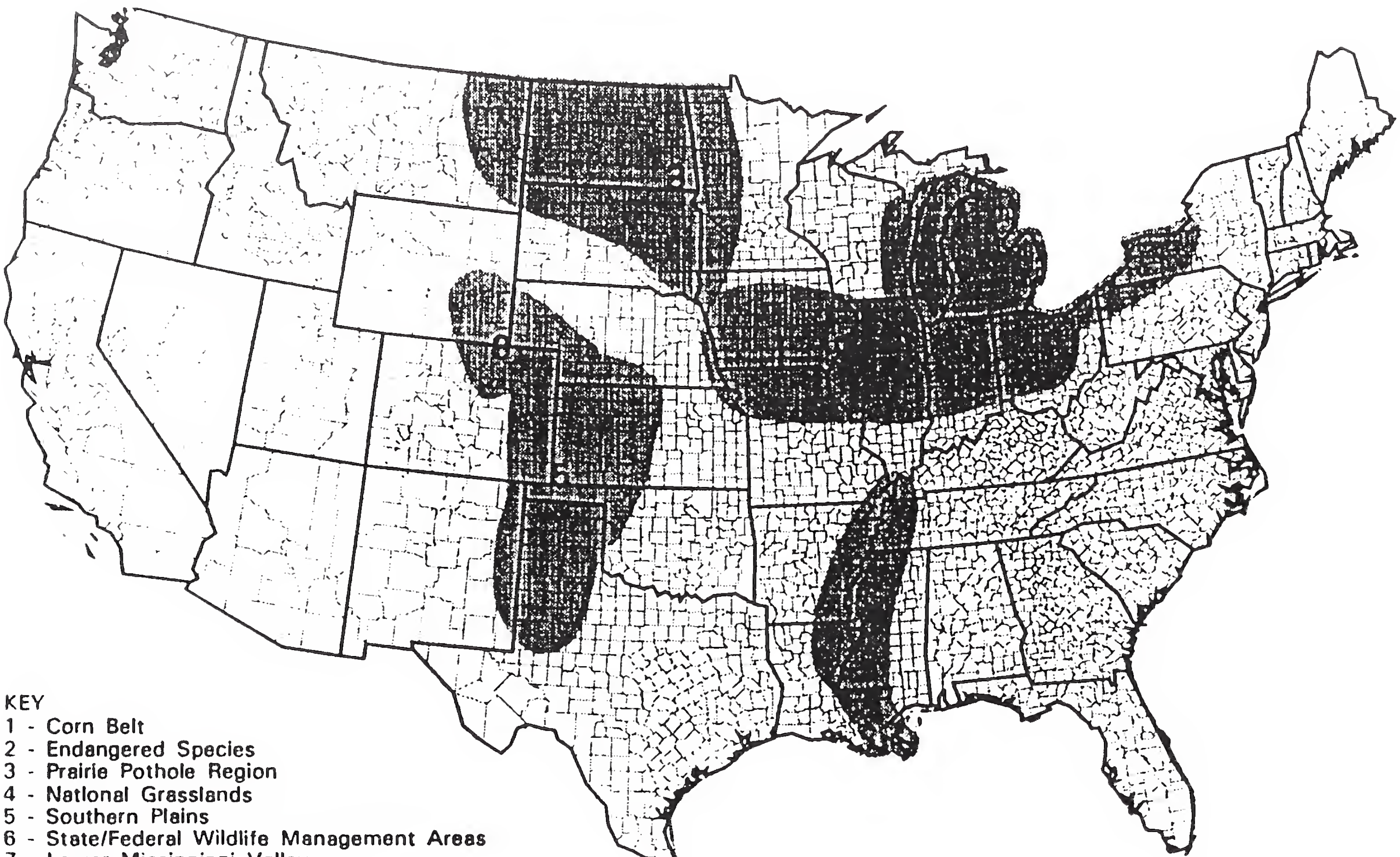
A recent study by the U.S. Congress Office of Technology Assessment (1995) determined that there are geographic areas or specific situations where USDA policies can have significant beneficial effects on environmental quality. The study identified 10 geographic regions. Overall, determination of these wildlife priority areas (Figure 4.1) was based on the intensity of agricultural production, losses of unique habitats for declining species, the ability of agroecosystems to sustain viable populations of wildlife, protection of habitats that are integrally related to local or regional wildlife-related economic viability, and preservation of environmental benefits derived from USDA conservation policies already in place. The priority areas are generally based on relatively large geographic regions (e.g., Cornbelt region), as well as categories (i.e, endangered species), or specific kinds of lands (e.g, National Grasslands). This does not imply that the habitat/agriculture problems are uniform or equivalent across the entire selected region. Information with which to identify individual sites (e.g., counties, drainage basins) and refine practice or management system applications can best be provided by local, State, or Federal officials familiar with the unique regional issues and priorities.

Obviously, other agriculturally-related geographic regions included in the 10 priority areas are of concern due to their importance in providing wildlife habitat. For example, the Central Valley of California provides critical wintering habitat for migratory birds and declining species. Realistically, however, the price of agricultural land and residential/industrial development constrain the ability of USDA policy to substantially enhance habitat in this region, when compared with the potential benefits that may be realized for the same budget outlays in the Great Plains. Similarly, declining stocks of salmon in the Pacific Northwest are an issue of national importance. However, agriculture is only one of many factors (e.g, logging of northwestern forests; impoundment of major rivers and tributaries; commercial, subsistence, and recreational fishing; urban and industrial development) that affect the quality of habitat for these populations.

The following discussion provides a brief description of the concerns and criteria used in selection of the major wildlife priority areas. (Priority areas for endangered species (2), National grasslands (4), State/Federal wildlife management areas (6), and riparian buffer strips (9) are national in scope and therefore are not identified with specific geographic regions.)

Figure 4.1

Wildlife Priority Areas



KEY
1 - Corn Belt
2 - Endangered Species
3 - Prairie Pothole Region
4 - National Grasslands
5 - Southern Plains
6 - State/Federal Wildlife Management Areas
7 - Lower Missippippi Valley
8 - Platte River Headwaters
9 - Riparian Buffer Strips
10- Great Lakes

SOURCE: Office of Technology Assessment, 1995

CORNBELT (Priority Area 1)

In terms of the proportion of land farmed, chemical inputs, and alterations to wildlife habitat, the Cornbelt region is the most intensively farmed region in the country. A shift to large fields with minimal diversity in crops produced and infrequent rotations between crops has caused a region-wide loss of diversity in landscape composition. Elevated dependance upon chemical fertilizers to maintain high yields and herbicides/pesticides to control pests has contaminated surface waters and diminished the availability of vegetation and insects necessary to maintain adequate rates of reproduction for game birds. Elimination of small, non-cropped sites (e.g., fencerows, shelterbelts wetland, riparian zones) associated with intensive production have diminished the amount and distribution of permanent, year-to-year cover required for reproductive and security cover for both game and non-game species throughout the region.

These elements have had significant effects on the regional quality and distribution of habitat resulting in population declines of ring-necked pheasants, cottontail rabbits, bobwhite quail, ground-nesting birds and other species well adapted to agricultural land uses (Taylor et al. 1978; Edwards et al. 1979; Robinson 1991; Herkert 1990).

ENDANGERED SPECIES HABITATS (Priority Area 2)

The causes for species decline and endangerment are variable. However, agriculturally related land use has been identified as being a frequent national cause of habitat loss or alteration leading to species endangerment (Flather et al. 1994). Loss of grassland cover has affected numerous avian species in the Great Plains and Cornbelt regions. Greater dependance upon agrochemicals (fertilizers/pesticides) affecting surface water quality, wetland loss and de-watering or sub-minimum flows in streams/rivers have eliminated, or sharply curtailed, habitat for wetland and aquatic species. Excessive sedimentation from intensively farmed croplands has reduced spawning habitat and channelization of riverine ecosystems has reduced diversity and quality of wetland and aquatic habitats.

Implementation of CRP provisions to protect and enhance habitat for threatened or endangered species should generally be targeted toward those counties with greater numbers of these species or which contain the only known habitat for a species. Threatened and endangered species are located in all portions of the United States (Figure 4.2). However, the very highest priority areas are located primarily in the Florida, Texas, and the desert southwest (Table 4.4).

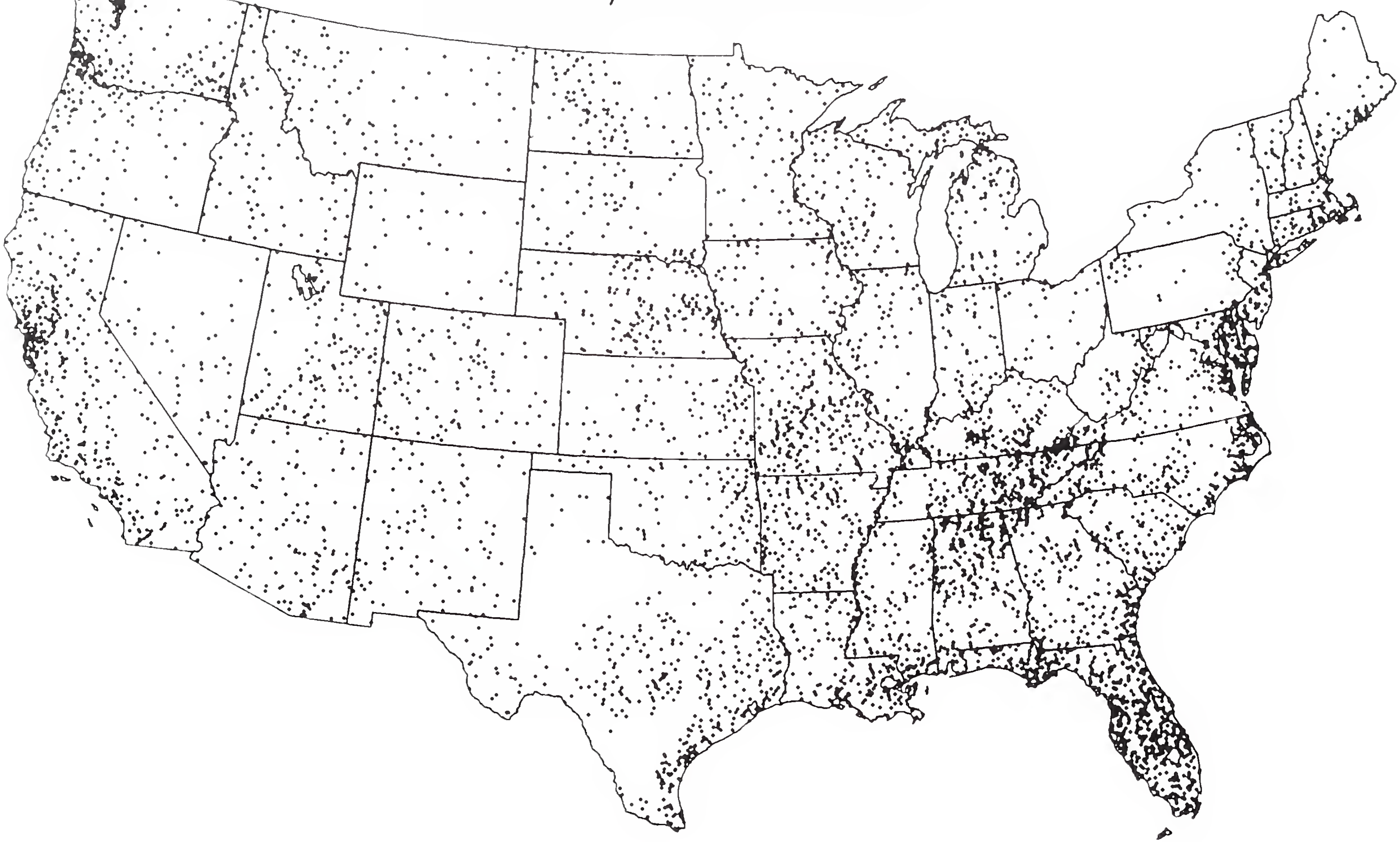
PRAIRIE POTHOLE REGION (Priority Area 3)

The Prairie Pothole Region is the major area of reproduction and migration habitat for waterfowl and shorebirds in the lower 48 states. The region also provides essential

Figure 4.2

Number of Threatened and Endangered Species

Where County Occurrence is Known



U.S. Fish and Wildlife Service

ESA/EPAS

Table 4.4. Taxonomic composition of high endangerment regions (number of species).

	Southern Appalachia	Peninsular Florida	Eastern Gulf Coast	Southern Desertic Basins, Plains, and Mountains	Arizona Basin	Colorado/ Green River Plateaus	Central Desertic Basins and Plateaus	Southern Nevada/ Sonoran Basin	Central/ Southern California	Northern California
Mammals	3	10	4	1	4	1		3	8	3
Birds	1	10	7	5	8	4		6	11	7
Fish	6	1	1	6	8	6	4	23	6	1
Reptiles		11	8					2	4	1
Amphibians								1	1	
Vertebrates	10	32	20	12	19	11	7	35	30	12
Clams	17									
Snails		1		2		1				
Insects		1						1	5	7
Crustaceans	1	1		1						1
Invertebrates	18	3		3		1		1	5	8
Animals	28	35	20	15	19	12	7	36	35	20
Plants	11	29	7	17	8	17	11	17	14	12
Total	39	64	27	32	27	29	18	53	49	32
Endemics 1/										
Total	2	17	2	15	5	7	4	20	16	13
Plant	1	10		10	2	7	4	7	11	7

1/ Endemics refers to species whose range is thought to be restricted to a single county.

habitat for grassland-dependent game and non-game avian species. Agricultural use has had a major impact on the regional abundance and quality of wetlands. The majority of the more temporary wetlands, important to both shorebirds and waterfowl, have been converted to farmland. A key factor contributing to waterfowl reproduction is the presence of high quality grassland vegetation that provides essential nesting cover for many species. Wetlands alone cannot produce ducks, the presence of grasslands associated with wetlands is essential to maintain populations of waterfowl and upland avian species. Relatively large blocks of grassland are necessary to avoid higher rates of predation and lower reproductive success associated with small, isolated tracts of grassland. The large tracts of high-quality grassland habitat provided by the CRP in this region have been instrumental in reversing long-term downward trends in populations of upland-nesting waterfowl, as well as non-game and gamebird species.

NATIONAL GRASSLANDS (Priority Area 4)

Species endemic to grassland ecosystems have experienced declines in both abundance and distribution due to isolation and fragmentation of remaining habitats (Knopf 1994; Sampson and Knopf 1994). National Grasslands administered by the USDA do provide habitat for grassland-dependent species but the majority of grasslands remaining are fragmented, in that they contain farmed lands within their boundaries. Agricultural use isolates remaining grassland habitats limiting the ecological benefits of preservation of these ecosystems. Introduction of non-native grasses on grazed lands within National Grasslands had negative effects on endemic grassland fauna. Priority should be given to reduction of fragmentation/isolation of grassland cover within National Grassland boundaries prior to addition of lands outside of existing boundaries. However, retirement from cropping and conversion to native and mixed grass covers in areas adjacent to National Grasslands could significantly enhance the wildlife benefits provided by these critical resources.

SOUTHERN PLAINS (Priority Area 5)

The Southern Plains are a key region supporting declining mammalian and avian grassland-dependent species. Establishment of large contiguous blocks of native grassland can provide significant benefits to habitat for non-game and game species with associated increases in populations of game and declining grassland species. Provision of suitable wildlife habitat provides substantial benefits to consumptive and non-consumptive wildlife related recreation and economic support for small, rural communities.

STATE AND FEDERAL MANAGEMENT AREAS (Priority Area 6)

Wildlife habitat and wildlife-related recreational opportunities could be enhanced nationwide by improving habitat associated with Federal- and State-managed wildlife and recreation areas. Most State hunting areas receive high rates of use by the public

but are spatially isolated within intensively farmed regions. Expansion of the amount of suitable vegetative cover on cropland adjacent to these management areas would increase the effective area of habitat, resulting in enhanced populations of game/ non-game wildlife that furnish improved benefits for public use.

LOWER MISSISSIPPI VALLEY (Priority Area 7)

The Lower Mississippi Valley is a major wintering and migratory area for much of North America's waterfowl and shorebird populations. Additionally, the quality of habitat within this region affects the physiological fitness of wintering birds, influencing reproductive success during the following breeding season. Elevated rates of sedimentation and agricultural chemical runoff have implications for costal wetland ecosystems and estuarine habitats essential for reproduction of coastal fisheries. The region suffered major losses of habitat in recent decades due to conversion of wetlands and bottomland forest to agricultural production. Siltation and contamination by agrochemicals continue to affect the quality of remaining wetland habitats. Hydrologic restoration of many Mississippi tributaries and floodplain wetland rejuvenation is needed to increase the quality of wildlife habitats.

PLATTE RIVER HEADWATERS (Priority Area 8)

The headwaters region of the Platte River represents an ecologically important portion of the shortgrass prairie ecosystem. Grassland-dependent species are experiencing drastic declines in numbers and distribution due to elimination and fragmentation/isolation of remaining habitat from agricultural and urban development activities. There is growing concern about status and distribution of fish species endemic to grassland ecosystems due to habitat losses resulting from agrochemicals in surface/ground waters and sedimentation from croplands. There has been a virtual elimination of prairie dogs (>90% of colonies) due to poisoning by agricultural interests, cropland conversion, and urban expansion. The prairie dog is a "keystone" species that provides beneficial habitat conditions for other declining species (e.g., burrowing owl, mountain plover) and numerous species of raptors including wintering bald eagles.

RIPARIAN AREAS (Priority Area 9)

Escalation in production intensity of rowcrops and a growing reliance on chemical fertilizers and pesticides have contributed to losses in the diversity and quality of aquatic habitats and elevated presence of agrochemicals in aquatic ecosystems (Paragamian 1990; Schottler and Eisenreich 1994). Agriculture has been identified as largest source of nonpoint source water pollution. Extensive channelization of riverain systems has eliminated or severely degraded riparian habitats. Quality, availability, and productivity of aquatic habitats have been reduced by as much as 90 percent in some midwestern river systems. Improved riparian vegetation and buffer strips can

reduce sediment and nutrient concentration in agricultural runoff by more than 90 percent providing benefit to aquatic and wetland associated wildlife. Enhancement of riparian habitats could benefit migratory birds, freshwater and anadromous fisheries, and local populations of game species. About 4.4 million acres of cultivated cropland are located within 100 feet of a stream or other waterbody (Table 4.5). Much of this land is located in Corn Belt, Lake States, or Appalachian regions (Figure 4.3).

GREAT LAKES BASIN (Priority Area 10)

Agricultural and urban development have had major impacts to riverain systems/riparian areas in midwestern drainages due to channelization and agrochemical contamination of tributary surface waters. Coastal wetlands/marshes have been lost or severely degraded resulting in drastic reductions in aquatic habitats and implications for water quality and fisheries in Great Lakes ecosystems. Channelization, and agrochemical and sediment-laden runoff from agricultural fields have further degraded the quality of aquatic habitats resulting in loss of spawning habitats, diminished physical structure, and elevated temperatures affecting fish populations in tributaries as well as the Great Lakes themselves.

Table 4.5. Cultivated Cropland: Riparian Areas 1/

Region	Acres (1,000)
Northeast	312
Appalachian	551
Southeast	232
Delta	427
Corn Belt	1,358
Lake States	604
No. Plains	317
So. Plains	186
Mountain	158
Pacific	209
U.S.	4,354

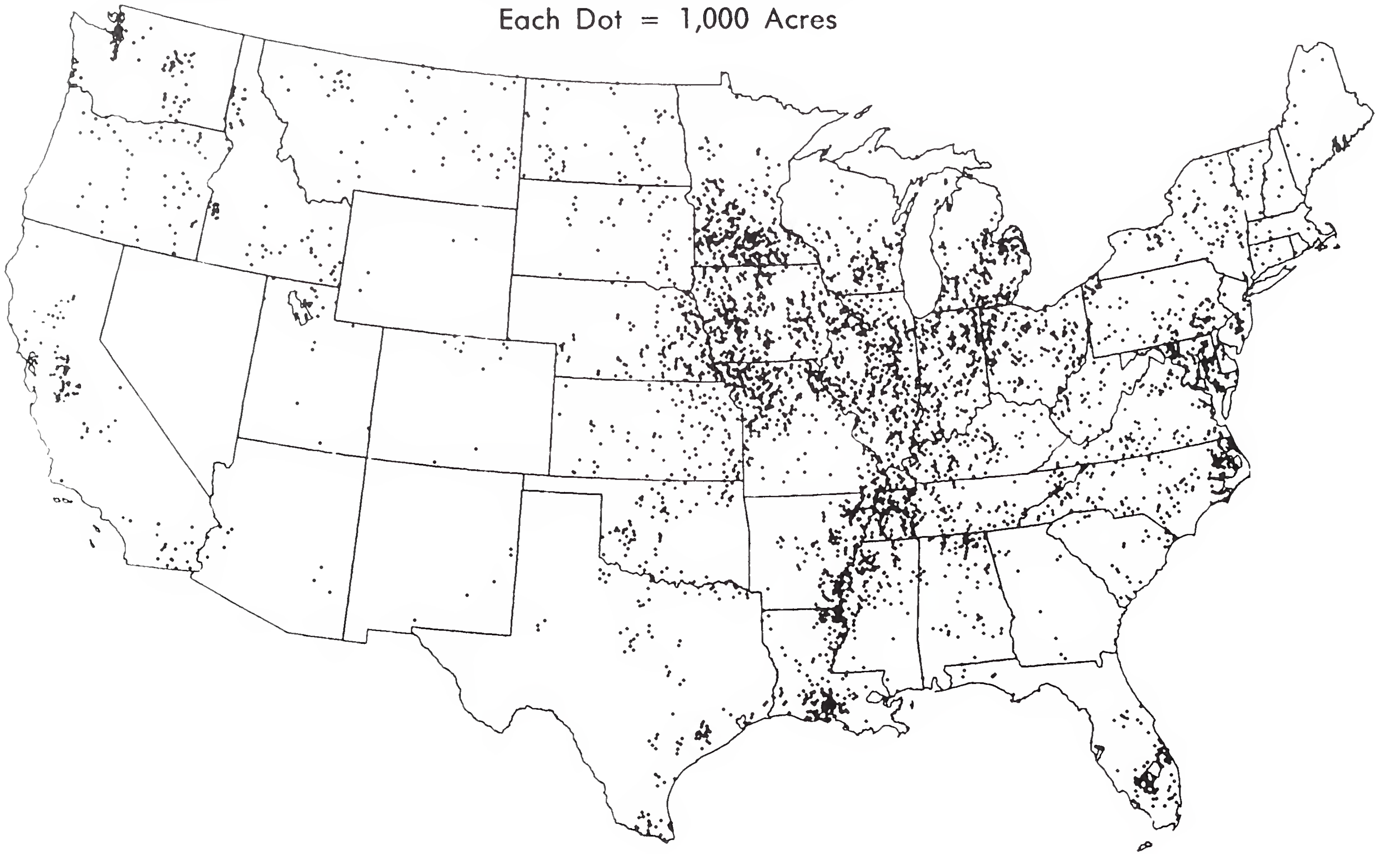
1/ Based on 1992 NRI (<100' to water).

In most situations the conservation of wildlife in agricultural ecosystems depends more on the management of on-farm land use than establishment of widely scattered reserves and permanent removal of agricultural land from production. While there are situations where preservation of natural ecosystems in more beneficial for some species, the main emphasis in selection of wildlife priority areas has been based on enabling ecologically viable communities to exist in collaboration with economically sustainable agricultural land use. National Grasslands could be more effective in supporting wildlife if internal fragmentation were

Figure 4.3

Cultivated Cropland in Riparian Areas (<100' to Water)

Each Dot = 1,000 Acres



Based on 1992 National Resources Inventory

ECA/EPAS

reduced. The wildlife and recreational benefits of State/Federal wildlife management areas could be enhanced if they were buffered from intensive agriculture by suitable wildlife covers in a long-term program. Adoption of wildlife-friendly practices on croplands such as more judicial use of pesticides/herbicides has been shown to benefit gamebird populations while still permitting production of crops (Southerton et al. 1993). Similarly, greater use of grassed waterways and establishment of permanent cover along riparian areas in agricultural ecosystems provides cover, reduces sediment and agrochemical runoff, and appreciably improves habitat for both terrestrial and aquatic species.

FERTILIZER APPLICATION

Commercial fertilizer use depends on a number of factors including soil, climate, technology, weather, crop mix, crop rotations, and commodity and fertilizer prices. Total fertilizer use is predominately determined by total planted acres because application rates and percentage of acres treated have become relatively stable.

Total U.S. fertilizer use rose from 7.5 million tons in 1960 to a record 23.7 million tons in 1981 (USDA 1994). The relative use of nitrogen increased more rapidly. Nitrogen use in 1960 was about 37 percent of total fertilizer use. By 1981, nitrogen use had increased 335 percent to over 50 percent of the total fertilizer used. The relative use of nitrogen leveled off at about 55 percent of total fertilizer used by 1993 (Table 4.6). This relative use change has resulted primarily from favorable crop yield responses, especially corn. Phosphate's share of total fertilizer use declined from 34.5 percent in 1960 to 21.1 percent by 1993. Potash use, historically below that of both nitrogen and phosphate, exceeded phosphate use for the first time in 1977 and will likely retain that position. In 1993, potash accounted for 24 percent of total fertilizer use.

The Corn Belt uses more fertilizer than any other region. Corn, the most fertilizer-intensive of the major field crops, historically has used around 45 percent of all fertilizer. However, from 1984 to 1993, nitrogen use in the Corn Belt decreased from 3.3 million tons to 3.0 million tons. Phosphate and potash use followed similar trends. Fewer crop acres have been planted in the Corn Belt since 1981 because of commodity acreage reduction programs and the CRP. Thus total fertilizer use in the Corn Belt has declined even though both application rates per fertilized acre and proportion of acres treated have increased slightly. The Northern Plains is the second highest user of nitrogen and phosphate.

It is expected that the CRP resulted in a decrease in total fertilizer use in the United States. The net change in acres in agricultural production due to the CRP, by commodity, by region, for the seven basic commodities, were used to estimate fertilizer use reductions. Since fertilizer use varies by the commodity produced and geographic area, State level fertilizer use rates by commodity were used to derive these estimates. These estimated reductions due to the CRP were added to U. S. totals to derive Table 4.7.

Table 4.6. Total 1993 U.S. Fertilizer Use (with CRP)

Region	Nitrogen	Phosphate (1,000 Tons)	Potash
Northeast	350	211	262
Appalachian	705	410	575
Southeast	682	314	680
Delta States	615	172	288
Corn Belt	2,954	1,288	1,989
Lake States	1,073	474	680
Northern Plains	2,090	646	134
Southern Plains	1,235	340	168
Mountain	744	296	80
Pacific	900	303	244
Total	11,347	4,454	5,100

Table 4.7. Estimated 1993 U.S. Fertilizer Use (without CRP)

Region	Nitrogen	Phosphate (1000 Tons)	Potash
Northeast	363	218	272
Appalachian	721	420	591
Southeast	692	321	691
Delta States	623	181	303
Corn Belt	3,092	1,377	2,114
Lake States	1,123	501	715
Northern Plains	2,301	753	251
Southern Plains	1,319	380	205
Mountain	769	308	90
Pacific	917	310	246
Total	11,921	4,770	5,477

The major nutrients that pose a risk to the environment are nitrogen and phosphorus. Nitrogen continually cycles among plants, soil, water, and the atmosphere, while phosphorus is less readily available due to adhesion to the clay particles of soil, moving into water bodies through sedimentation and siltation. Excess nitrogen can run-off and leach through the soil, potentially polluting both ground and surface water. Phosphorus contained in sediments and

Figure 4.4

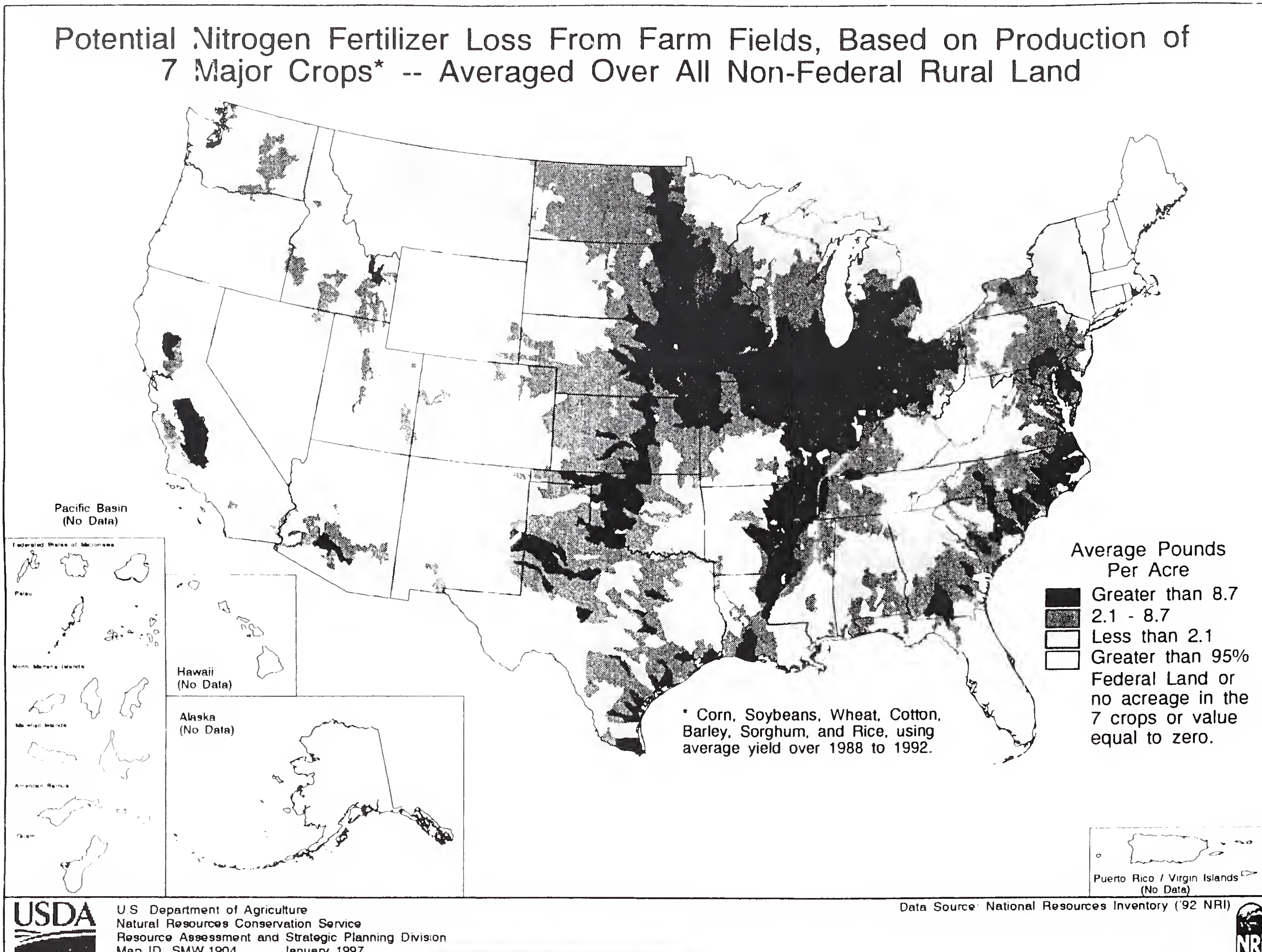
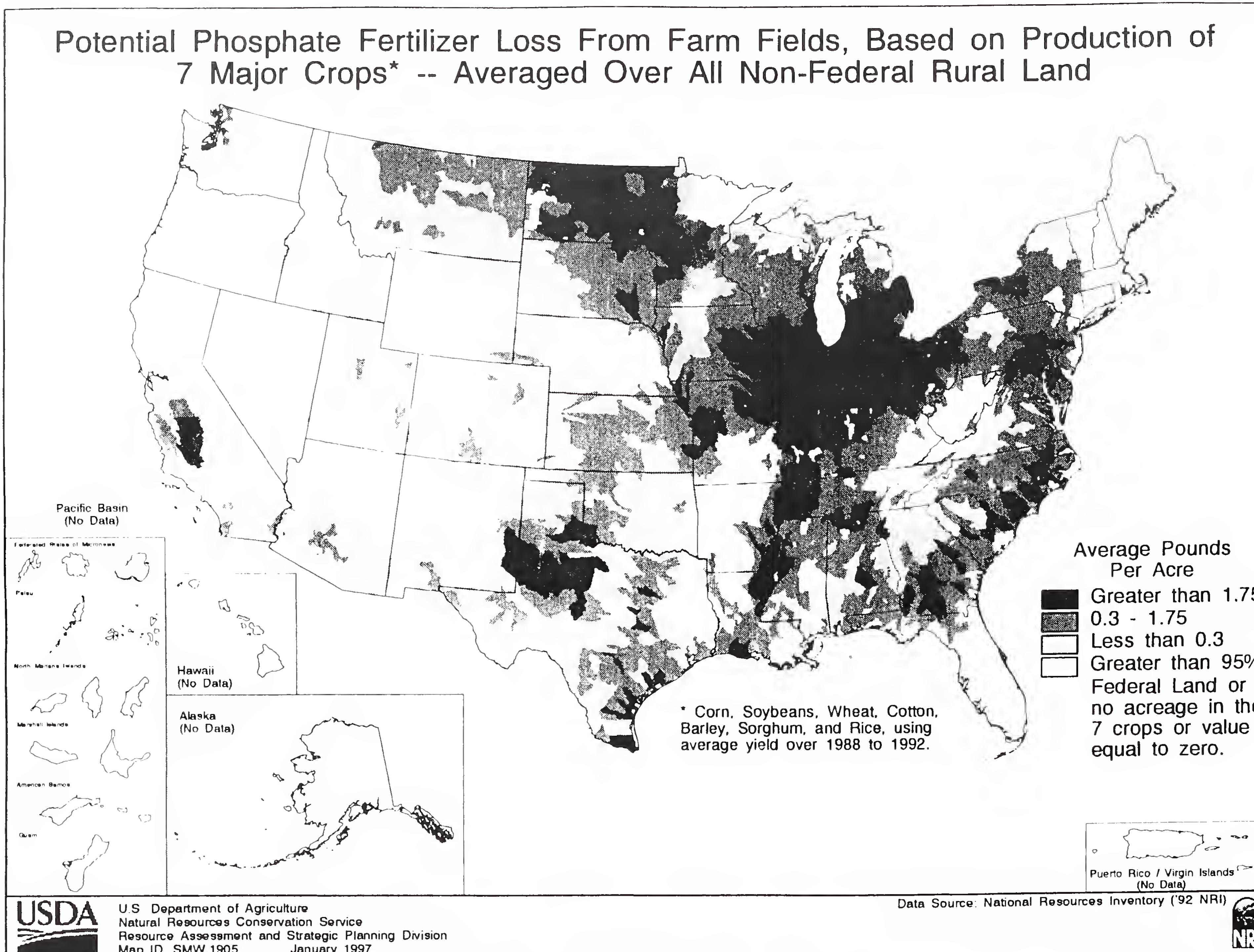

Potential Nitrogen Fertilizer Loss From Farm Fields, Based on Production of 7 Major Crops* -- Averaged Over All Non-Federal Rural Land
Pacific Basin (No Data)
Hawaii (No Data)
Alaska (No Data)
Puerto Rico / Virgin Islands (No Data)
Average Pounds Per Acre
Greater than 8.7
2.1 - 8.7
Less than 2.1
Greater than 95% Federal Land or no acreage in the 7 crops or value equal to zero.
* Corn, Soybeans, Wheat, Cotton, Barley, Sorghum, and Rice, using average yield over 1988 to 1992.
USDA
U.S. Department of Agriculture
Natural Resources Conservation Service
Resource Assessment and Strategic Planning Division
Map ID: SMW.1904 January 1997
Data Source: National Resources Inventory ('92 NRI)
NRI

Figure 4.5



Potential Phosphate Fertilizer Loss From Farm Fields, Based on Production of 7 Major Crops* -- Averaged Over All Non-Federal Rural Land
Pacific Basin (No Data)
Hawaii (No Data)
Alaska (No Data)
Puerto Rico / Virgin Islands (No Data)
Average Pounds Per Acre
Greater than 1.75
0.3 - 1.75
Less than 0.3
Greater than 95% Federal Land or no acreage in the 7 crops or value equal to zero.
* Corn, Soybeans, Wheat, Cotton, Barley, Sorghum, and Rice, using average yield over 1988 to 1992.
Data Source: National Resources Inventory ('92 NRI)
USDA
U.S Department of Agriculture
Natural Resources Conservation Service
Resource Assessment and Strategic Planning Division
Map ID SMW 1905 January 1997

siltation do not generally leach into the groundwater and primarily affect surface water quality.

Fertilizers in and of themselves do not generate environmental damage. Only when fertilizers are applied in excess of the level that crops utilize do fertilizers pose a potential environmental threat. A detailed estimate of nitrogen and phosphorous loadings potentially available for leaching or runoff were estimated by watershed by Kellogg and Wallace (1996). State-level data on fertilizer application rates and percent of acres treated for the seven basic commodities were compared to the amount of nitrogen and phosphorous estimated to be taken up by the crop and removed from the field at harvest. In estimating excess nitrogen, an adjustment was made for legumes grown in the previous year, but no adjustment was made for nitrogen from livestock manure applications. The resulting estimates of potential nitrogen and phosphorous losses from farm fields (Figures 4.4, 4.5) can be used to identify areas of the country where the application of commercial fertilizers to farm fields could result in relatively large nitrogen or phosphorous loadings to the watershed. Excess nitrogen available for leaching or runoff is highest in the Midwest, (eastern Nebraska to Ohio), North Dakota and northwest and southern Minnesota, parts of Texas, and scattered watersheds along the Atlantic Coastal Plain. Excess phosphorous available for runoff is highest in many of the same areas where excess nitrogen loadings are high. The largest differences occur in South Dakota where excess phosphorous is much higher than nitrogen and Iowa, southern Minnesota, and eastern Nebraska where excess phosphorous is much less than excess nitrogen.

PESTICIDE APPLICATION

Pesticide use grew from 233 million pounds in 1964 to 612 million pounds in 1982. This increase was due to a number of factors including larger cropland acreage, greater proportion of acres treated, and higher application rates per acre treated. Since 1982, annual pesticide use has declined. The primary cause of the reduction is the decrease in cropland in agricultural production. The proportion of acres treated has remained relatively constant and the application rate per acre treated has declined slightly (USDA 1994).

On a per-acre basis, corn is an intensive pesticide user. Corn acreage received 245 million pounds of pesticides in 1992, accounting for 43 percent of total pesticides used (Table 4.8). Corn represents the largest acreage of any crop on which pesticides are used (Table 4.9).

Soybeans were the second largest user of pesticides in 1992, receiving about 68 million pounds. Soybeans accounted for about one-fourth of the acreage in the U.S. and used about 12 percent of the pesticides.

Wheat has the second largest acreage, but was the least intensive pesticide user of the major crops. Many wheat acres (around 45 percent) receive no pesticides. Wheat accounts for 29 percent of the acres in 1992, but only about 3.5 percent of the pesticides used.

Cotton, with 13 million planted acres and nearly 58 million pounds of pesticides applied, accounted for 5 percent of total acreage and 10 percent of total pesticide use.

Table 4.8. Total 1992 U. S. Pesticide Use

Commodity	Herbicides	Insecticides	Other	Total
	(1,000 Pounds of Action Ingredient)			
Corn	224,403	20,870	0	245,272
Cotton	25,871	15,365	16,629	57,865
Sorghum	16,995	1,368	0	18,362
Wheat	17,398	1,153	1,155	19,706
Soybeans	67,529	360	85	67,974
Other	35,979	18,739	110,010	164,728
Total	388,175	57,855	127,877	573,907

Table 4.9. Total 1992 U.S. Planted Acres

Region	Corn	Cotton	Sorghum	Wheat	Soybeans	Other	Total
	(1,000 Acres)						
Northeast	3,587	0	0	613	1,195	5,666	11,061
Appalachian	3,895	1,027	127	1,481	4,050	7,258	17,838
Southeast	1,605	1,122	155	740	1,685	3,676	8,983
Delta States	780	3,240	820	1,270	6,220	4,972	17,302
Corn Belt	36,800	335	940	4,155	30,300	10,314	82,844
Lake States	13,800	0	0	3,552	7,700	10,200	35,254
N. Plains	14,950	2	5,580	28,105	7,400	21,273	77,310
S. Plains	1,900	5,907	5,110	9,700	630	7,892	31,139
Mountain	1,434	496	445	9,832	0	11,550	23,757
Pacific	540	1,110	0	3,977	0	5,648	11,275
Total	79,300	13,200	13,200	63,400	59,200	88,500	316,800

Long-term conversion of cropland to conservation cover would decrease total U.S. pesticide use. The net change in acres in agricultural production, for the seven principle commodities, by region, provide an estimate of pesticide use reductions. Since pesticide use varies as a function of the commodity produced and geographic area, State level pesticide use rates by commodity were used to estimate average annual pesticide use reductions (Table 4.10).

Once a pesticide is applied, fate and transport of the compounds are determined by a number of processes. These include photo decomposition, chemical degradation, biological degradation, volatilization, plant uptake and metabolism, adsorption to soil, run-off and leaching. Adsorption is the binding of pesticides to soil particles and affects the potential movement of a pesticide to ground or surface water. Run-off is the surface movement of pesticides in water. Pesticides can move either dissolved in water or adsorbed to soil particles. Leaching is the movement of pesticides in water through the soil profile and is dependent of pesticide properties and soil permeability. Deep percolation or run-off of pesticides require rainfall or irrigation. The following maps show the combined influences of potential pesticide run-off and pesticide leaching for the United States (Figures 4.6 and 4.7).

Table 4.10. Estimated CRP Pesticide Use Reductions (average annual).

Region	Barley	Corn	Cotton	Oats	Sorghum	Wheat	Soybeans	7 Crops
				(1,000 Pounds of Active Ingredient)				
Northeast	2	475	0	1	2	6	32	520
Appalachian	2	483	26	0	13	12	182	718
Southeast	0	307	30	0	12	7	145	501
Delta	0	67	214	0	46	11	381	719
Corn Belt	0	4,808	9	3	82	16	1,419	6,337
Lake States	18	1,420	0	5	6	50	269	1,769
No. Plains	85	1,106	0	5	669	368	229	2,461
So. Plains	3	210	123	1	646	217	25	1,225
Mountain	118	69	17	1	74	246	0	526
Pacific	58	55	58	1	31	172	0	374
U.S.	286	9,001	476	17	1,581	1,104	2,683	15,148

Figure 4.6

Pesticide Runoff Loss Potential (Dissolved plus Adsorbed) by Watershed for Field Crop* Production -- Averaged Over Non-Federal Rural Land

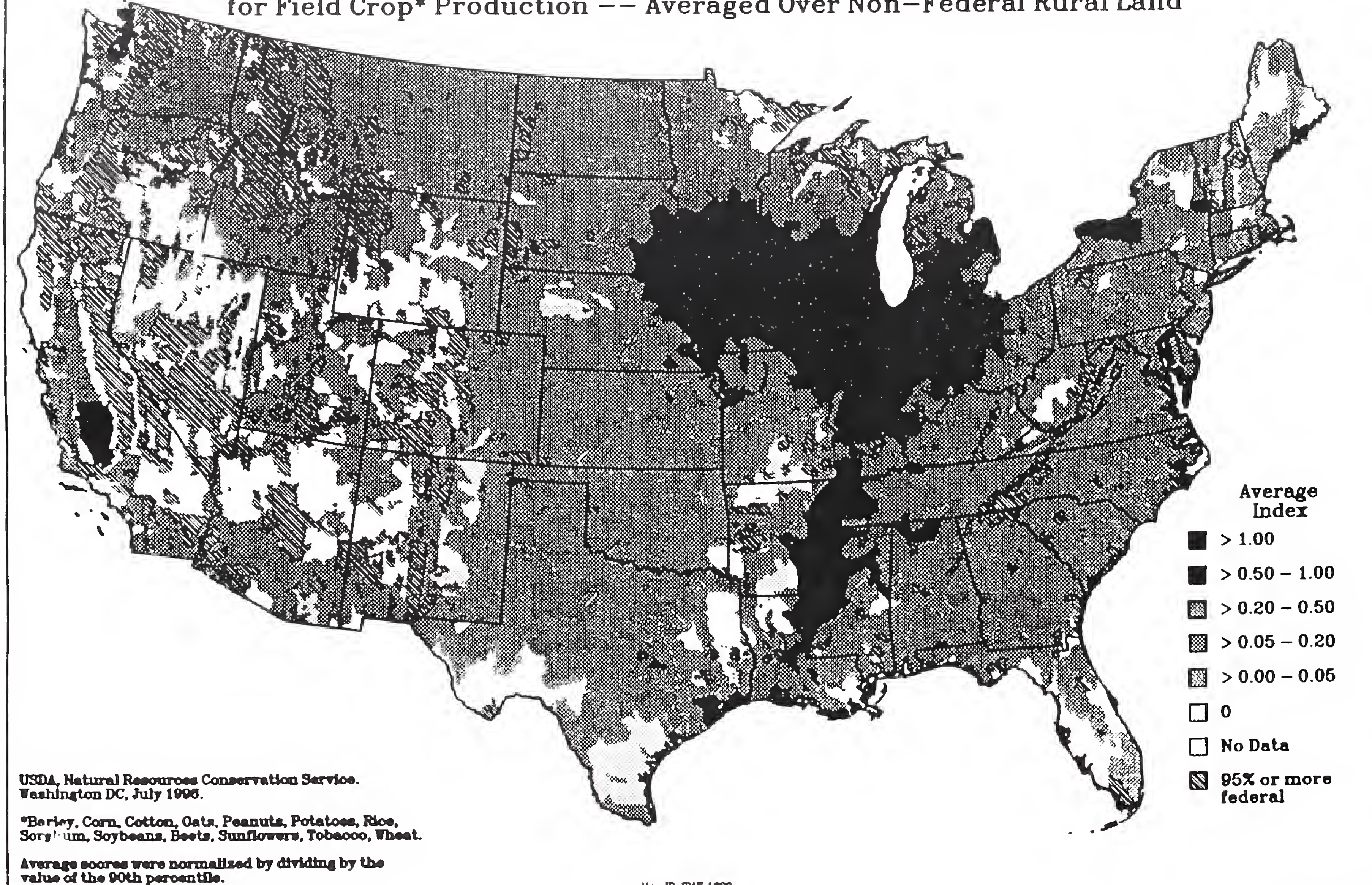
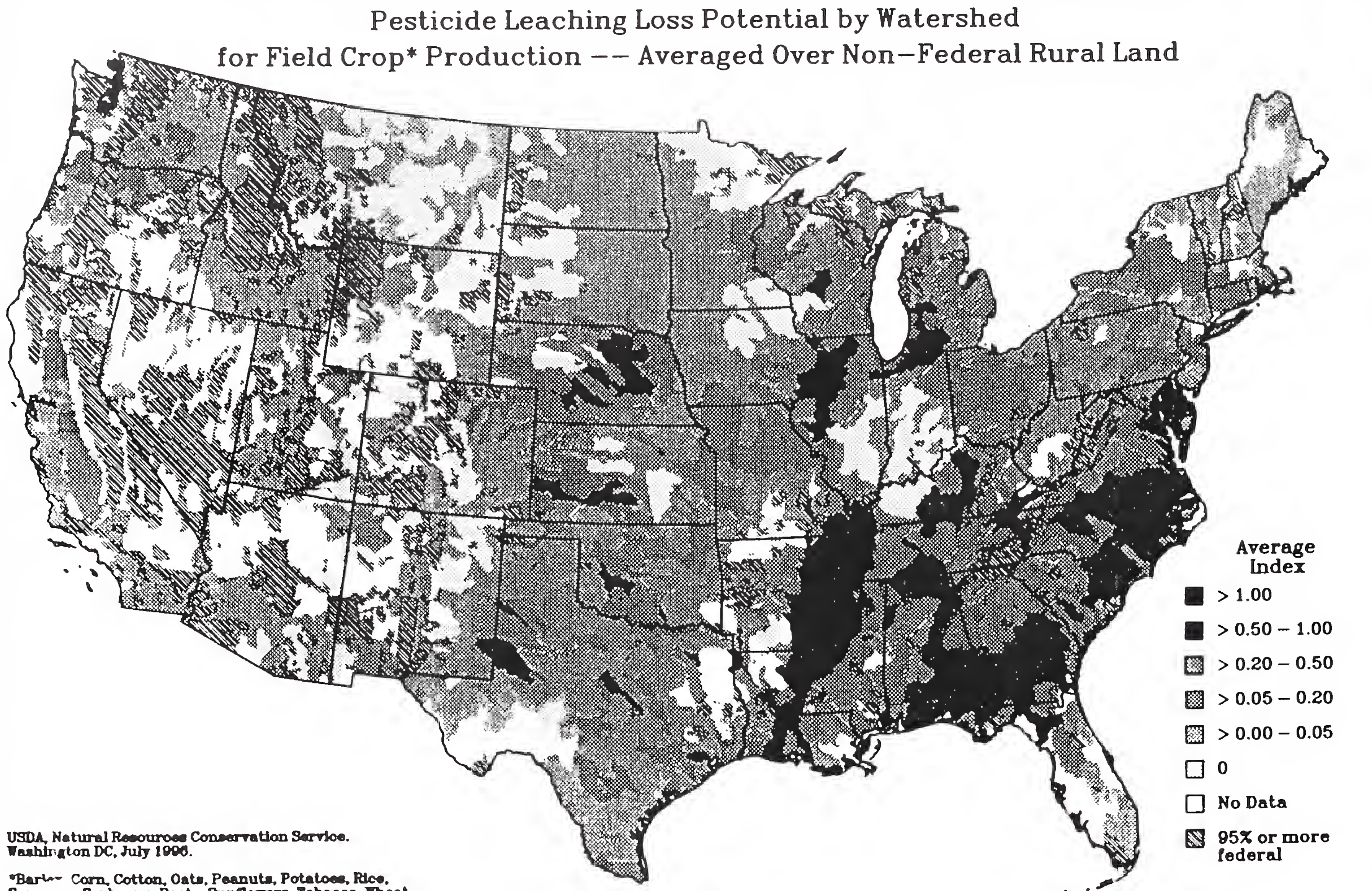


Figure 4.7



USDA, Natural Resources Conservation Service.
Washington DC, July 1996.

*Bar[illegible] Corn, Cotton, Oats, Peanuts, Potatoes, Rice,
Sorg[illegible], Soybeans, Beets, Sunflowers, Tobacco, Wheat.

Average scores were normalized by dividing by the
value of the 90th percentile.

WETLANDS

Long-term conservation of cropped wetlands and their adjacent uplands help to restore and protect wetland functions and values--increase wildlife habitat, improve water quality, and provide flood protection. If converted to permanent cover and noncropped uses, these acres would be extremely valuable because of the multiple environmental benefits provided.

The Delta States and the Northern Plains account for the largest amount of cropped wetlands in the U.S. with each accounting for almost 29 percent of the total (Table 4.11). The next highest region, the Lake States, accounts for only a little more than 15 percent of the total cropped wetlands (Figure 4.8).

Table 4.11. Cropped Wetland Acres

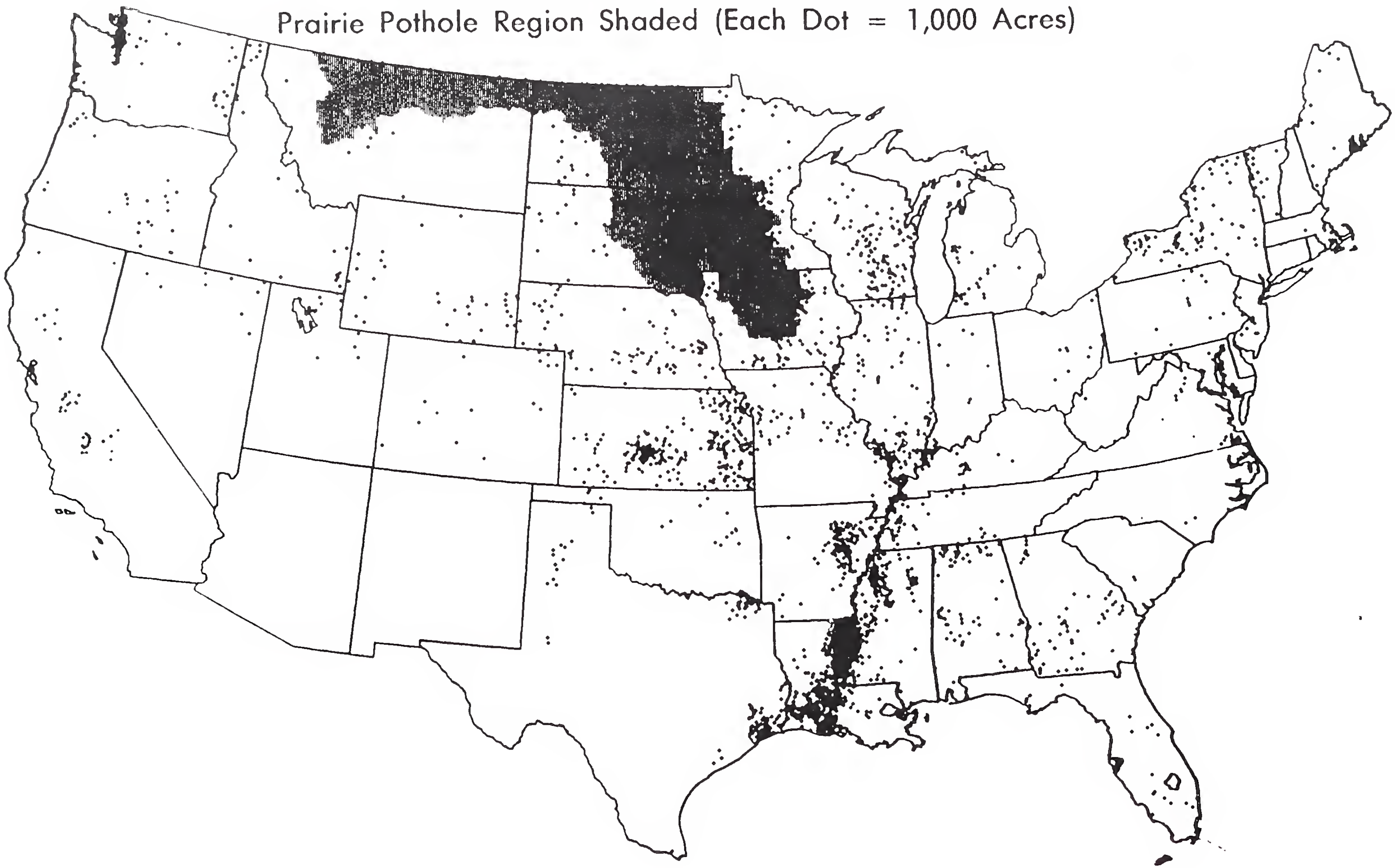
Region	Cultivated Wetland Acres (1,000)
Northeast	400
Appalachian	200
Southeast	400
Delta States	2,600
Corn Belt	200
Lake States	1,400
Northern Plains	2,600
Southern Plains	400
Mountain	300
Pacific	200
Total	9,100

Wetland functions are the physical, chemical, and biological processes that characterize wetland ecosystems, such as flooding, denitrification (removing nitrogen from water and sediment), provision of habitat, and support of aquatic life. These wetland functions provide extensive environmental benefits, including flood damage abatement, sediment and nutrient reduction in water flows, wildlife habitat, recreation, and water supply. Wetlands can also provide timber and be used for educational and research purposes. Wetlands also have aesthetic values. As the number of wetland acres decline, their functions and values become more important.

Figure 4.8

Cropped Wetlands (Cultivated Cropland)

Prairie Pothole Region Shaded (Each Dot = 1,000 Acres)



Based on 1992 National Resources Inventory

FSA/EPAS

END NOTE

From the information reviewed during preparation of this analysis, it is clear the production activities on cropland can sometimes lead to adverse impacts on elements of the natural resource base that are to be protected under the 1996 Act (e.g., soil, water, wildlife habitat, wetlands, and air. However, the significance and severity of these impacts vary widely according to the specific nature and characteristics of the resource base, (e.g., location, soil type, topology, climatic conditions, etc.), the crops produced, and differences in management and land use practices. These differences imply that there must be careful differentiation and discrimination among the different types and degrees of resource degradation when identifying cropland that should be converted to noncropping uses through enrollment in CRP.

Thus, policy makers and program managers must insure that land eligibility and selection standards are carefully defined such that they accurately address or target the appropriate resource degradation situations. The issues raised and analyzed in this risk assessment help in focusing CRP selection criteria to ensure maximum environmental benefits.

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